DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE

A PRELIMINARY ASSESSMENT OF WATER QUALITY AND BIOTA IN THE SERPENTINE AND NICOMEKL RIVERS AND MAHOOD CREEK

1974-75

Regional Program Report: 82-17

by

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ABSTRACT

A program of regular sampling for 16 routine water quality parameters; bottom macrointervertebrate populations; periphyton populations, biomass and pigment content; and levels of various metals in fish flesh was undertaken on Mahood Creek and the Serpentine and Nicomekl Rivers from June 1974 until November 1975. Salmonid populations in these streams could be harmed if intensive farming practices in the lowlands and increased urbanization in the uplands is not managed to protect water quality and maintain adequate water flows.

RÉSUMÉ

Un programme d'échantillonnage standard pour 16 paramètres routiniers de qualité d'eau; les populations macro-invertébrées du fond marin; les populations périphytiques, la biomasse et la teneur en pigment; ainsi que les niveaux de divers métaux dans la chair des poissons a été entrepris à Mahood Creek et sur les rivières Serpentine et Nicomekl de juin 1974 à novembre 1975. Les populations salmonids de ces cours d'eau pourraient être affectées négativement si les practiques agricoles intensives dans les plaines et l'urbinization croissante des régions plus élevées ne sont pas administrées de façon à préserver la qualité de l'eau et à maintenir des débits d'eau adéquats.

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SUMMARY AND CONCLUSIONS

Seasonal trends were obvious for most of the parameters measured. Measurements were generally high during later spring and summer and low in winter for temperature, oxygen saturation, pH, total residue, volatile residue (but not in Mahood Creek), alkalinity and conductivity (Table 1). Other parameters measured were low during the summer then increased with the fall rains and remained high over the winter. These are: colour, turbidity, organic carbon, nitrite-nitrate nitrogen, ammonia (except in summer, 1974 when levels were high), phosphate (except in the Serpentine and station 4 of the Nicomekl where summer irrigation kept levels high), and total hardness. Only non-filterable residue levels did not vary consistently with time.

Fewer parameters showed obvious interstream differences. Summertime temperatures were lower in Mahood Creek than in the mainstem rivers and thus more suitable for fish, while oxygen saturation levels during winter were higher in Mahood and thus also better for fish eggs and fry. Colour, total residue, non-filterable residue, carbon, phosphate and conductivity levels were also lowest in Mahood Creek. Temperature, turbidity, non-filterable residue and total carbon were highest at stations in the Serpentine, while total residue and phosphate levels were highest at stations in the Nicomekl. Oxygen, colour and conductivity were similar in the Serpentine and Nicomekl.

None of the parameters measured increased from upstream to downstream stations in Mahood Creek, on the contrary, summer oxygen saturation levels, pH and total residue were highest at the upstream station 1 which drains an urban area. The greatest increase in summer temperatures was noted at stations 1 and 4 of Mahood Creek where there was little streambank vegetation.

However, many of the parameters did show a distinct downstream increase in the mainstem rivers. In the Nicomekl, temperature, colour, total residue, non-filterable and volatile residues, total carbon, and

TABLE 1 SUMMARY OF TRENDS IN SEASONAL, INTERSTREAM AND INTERSTATION VARIATIONS RECORDED FOR PARAMETERS MEASURED IN THE NICOMEKL (N) AND SERPENTINE (S) RIVERS AND MAHOOD (M) CREEK.

	Seasonal Variation			Interstream Variation	Interstation Variation (number refers to station)		
River:	N	S	M		N	S	M
Parameter							
Temperature	summer tempertatures often too high for fish		summer temperatures acceptable for fish	yes, during the spring and summer only temperatures were highest in the Serpentine, lowest in Mahood Ck.	increased downstream	except 4 lowest	lowest at 1,4, -grass banks
O_2 Saturation	low in winter; supersaturated in summer minor peak, April	major peak, Sept.	peak-April	yes, during winter saturation levels were lower in the Nicomekl and Serpentine; best all year in Mahood Ck.	increased downstream	lowest at 1,2; highest 5,6	decreased downstream
pH	low in winter; high and variable spring, summer		slightly higher in summer; peak April	no	increased downstream in spring and summer only	increased downstream in spring and summer only, except at 4	decreased downstream
colour	peak-Nov lower in summer	peak-Nov	peak-Oct	yes, Mahood Creek was 2-3 times less coloured than the mainstem rivers	3,4, usually higher	lower; 1 low in summer	increased downstream
Turbidity	high-Nov-Feb. Low summer	high-June-Nov. Low Jan-March	low except for peaks in Nov 74, Oct 75	Nicomekl and Mahood similar; Serpentine was higher during "low" periods	except 1 usually lower		
Residue: a) Total	high June-November; low in winter and spring			yes, values highest in the Serpentine lowest in Mahood Ck.	increased downstream	increased downstream	higher at 1 only

TABLE 1 (continued) SUMMARY OF TRENDS IN SEASONAL, INTERSTREAM AND INTERSTATIONS VARIATIONS RECORDED FOR PARAMETERS MEASURED IN THE NICOMEKL (N) AND SERPENTINE (S) RIVERS AND MAHOOD (M) CREEK.

	Seasonal Variation			Interstream Variation	Interstation Variation (number refers to station)		
River:	N	S	M		N	S	M
b) Non-Filterable	1,2 only: high, variable Sept-May. Low, stable June, July. 3,4 variable throughout	high summer, fall. Low Jan-March	high Aug-Oct low April-July	yes, values lowest in Mahood Ck. Serpentine values highest in 1975; Nicomekl values highest in 1974.	3,4 slightly		4 higher
c) Volatile	peak June 74, decreased to Jan 75, remained stable until peak in Aug 75	same as Nicomekl		no difference during winter: but Serpentine and Nicomekl higher during peak periods	increased downstream	increased downstream	
Organic Carbon	all stations peaked Nov, 75; some stations lower in 1974; 1,2 lower June-Sept	1,2 lower June-Aug	not sampled in summer all stations lower in summer	yes, highest values in the Serpentine, lowest in Mahood Ck.	3,4 higher	except 4 lower	higher at 1,2 especially in summer
Phosphate	1,2,3 decreased in summer; increased with fall rains. 4, variable in 75	no trend, possibly due to summer, irrigation runoff	low, stable in summer, higher, variable in winter, spring	yes, in Mahood Ck. 70% of samples were less than 0.05mg/l; in Nicomekl and Serpentine samples all were greater than 0.05mg/l	3,4 higher in winter, fall	except 4 lower	except 4 higher summer, fall 75
Nitrite-Nitrate	all streams peaked in fall 74,75 and levels were higher in winter, lower in summer seasonal differences greatest at; 3,4	all but 4	1	no note: 1974 peak levels were 2-3 times greater than 1975 peak levels	3,4 lower in summer	4 higher-spring, summer	1, 4 usually lower

TABLE 1 (continued) SUMMARY OF TRENDS IN SEASONAL, INTERSTREAM AND INTERSTATIONS VARIATIONS RECORDED FOR PARAMETERS MEASURED IN THE NICOMEKL (N) AND SERPENTINE (S) RIVERS AND MAHOOD (M) CREEK.

	Seasonal Variation			Interstream Variation	Interstation Variation (number refers to station)		
River:	N	S	M		N	S	M
Ammonia	all streams had high levels in summer 1974 and winter 1974, 1975 but low levels in summer 1975			yes, during winter levels were higher in the Nicomekl		except 5,6 higher in winter	
Alkalinity	all streams: high spring to fall, low November to March			no			
Total Hardness	small peak April major peak in fall both years	small peak April major peak in fall both years	high Apr-Sept, low winter, fall	no, floodgates installed fall 74 decreased downstream levels on Serpentine and Nicomekl Rivers	3,4 higher, tidal influence	5,6 higher, tidal influence	
Conductivity	all streams highest in late summer, lowest in January, except;		1,2 peaked also in Jan, Feb	yes, lower in Mahood Ck., seasonal differences not so extreme	3,4 higher, tidal influence	5,6 higher, tidal influence	
Microinvertebrates	NOT ANALYZED			yes, fewer in Serpentine than Nicomekl	fewer downstream	3,5 fewer numbers	
Muscle Metals	NOT ANALYZED			no			

yes = Trend found

no = No trend found

total phosphate were higher all year at downstream stations 3 and 4 than at upstream stations 1 and 2. In the spring and summer when waters were supersaturated with oxygen, saturation and pH also increased downstream. Fewer parameters showed interstation differences in the Serpentine where all of the stations were adjacent to farmlands. Only total and volatile residue showed an increase at downstream stations year-round. Oxygen saturation, pH, and total carbon increased downstream in spring and summer only, while in winter, ammonia levels were higher at stations 5 and 6. Station 4 on the Serpentine was greatly affected by its position immediately downstream of the cleaner Mahood and had lower levels of most parameters measured. Definite downstream differences were also found in algae populations of the Serpentine. Station 4 had the largest populations while two species were more common upstream and two others more abundant at downstream stations. Algae samples were not available from Mahood Creek or the Nicomekl.

Most of the parameters measured met EPA Water Quality standards for fish. However, summer temperatures were often near lethal levels in the mainstem Nicomekl and Serpentine, and winter oxygen saturation levels over gravel beds in Mahood Creek were substantially less than the 100% recommended for maximum egg-to-fry survival. On occassion, pH also exceeded recommended levels when waters were supersaturated with oxygen in late summer.

1 INTRODUCTION

On the lower reaches of the Fraser River Valley, first logging and farming then extensive urbanization destroyed most of the fish bearing streams that once drained the municipalities of Vancouver, Burnaby, Coquitlam and Port Coquitlam (Proctor, 1978). Now streams which still sustain salmonid populations south of the Fraser River are also deteriorating as municipalities there seek increased urbanization and as dwindling farmlands are more intensively cultivated.

In 1974 the Environmental Protection Service initiated a study to determine changes in the water quality over a period of years of two of the major streams draining the land south of the Fraser: the Nicomekl and Serpentine Rivers (Figure 1). The landforms, surficial geology, soil types, hydrology, reach descriptions, and precipitation and temperature records of these rivers have been described in detail by Hirst et al. (1979, unpublished) and are reviewed only briefly here.

Together the Serpentine and Nicomekl watersheds encompass 33,870 hectares within the borders of the municipalities of Langley, Langley City and Surrey (Dick, 1975). The Serpentine River begins near Tynehead, Surrey, at an elevation of 75 m, and flows 29 km southwest to empty into Mud Bay. Its three main tributaries, Mahood, Hyland and Latimer Creek, rise at similar elevations and join the main river in its upland region. The Nicomekl and its major tributaries, Anderson and Murray Creek, rise respectively east and south of Langley City at elevations of about 90 m. The Nicomekl flows approximately 35 km west to enter Mud Bay 2.5 km south of the Serpentine.

West of 168 Street (Figure 2), the Nicomekl and Serpentine Rivers share a single flat bottomed valley and meander only 1.5 to 2 km apart through the lowland. Both are low gradient streams with over 90% of each course lying below 15 m and most of the lower floodplain (estimated at 4900 ha) lying between 1 and 2 m geodetic datum (Hirst et al., 1979). Stream gradients average one percent in the upper tributaries and decrease to 0.05% or less in the lowlands.

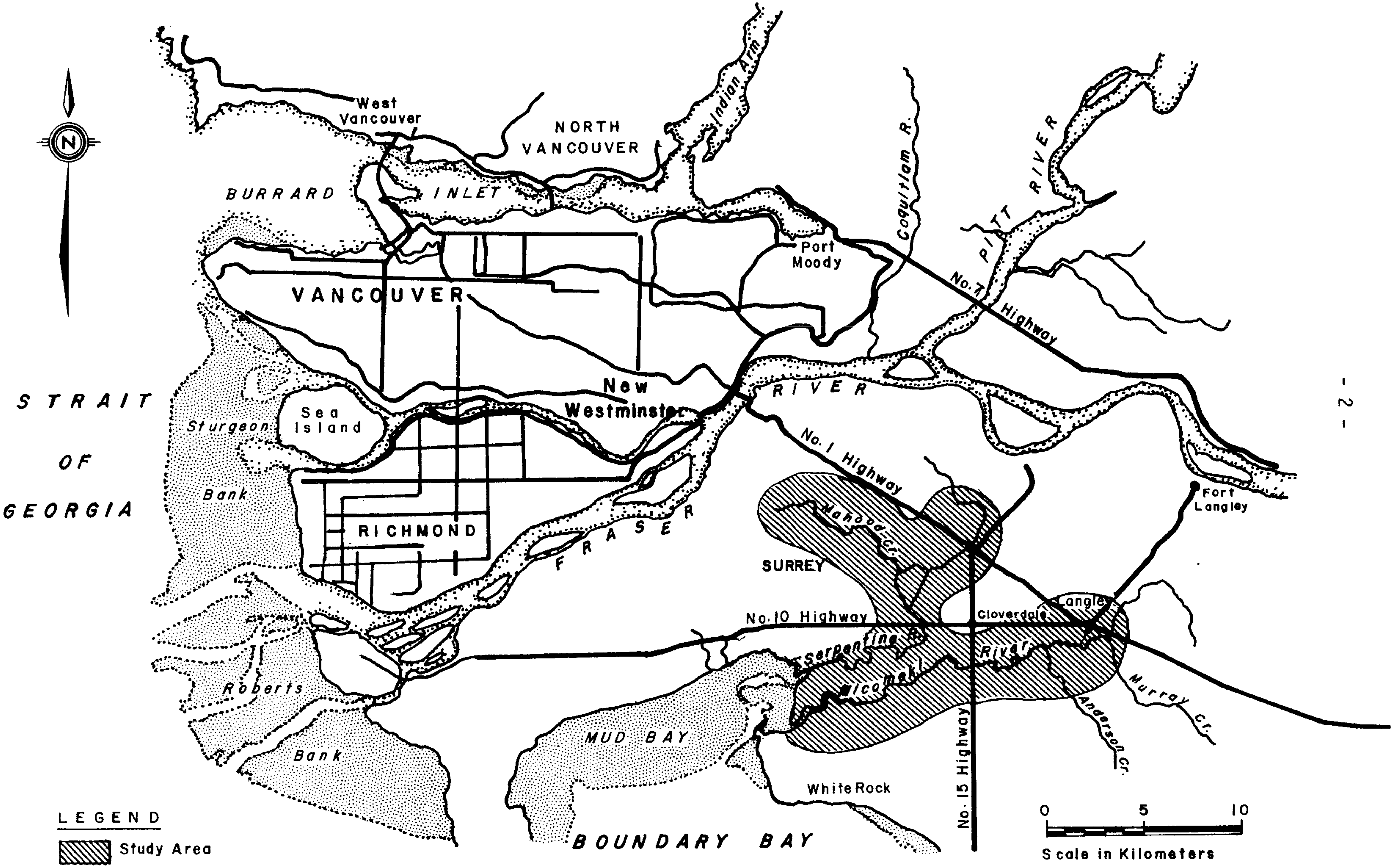

FIGURE I LOCATION OF THE SERPENTINE, NICOMEKL AND MAHOOD WATERSHEDS IN THE LOWER FRASER RIVER VALLEY, BRITISH COLUMBIA

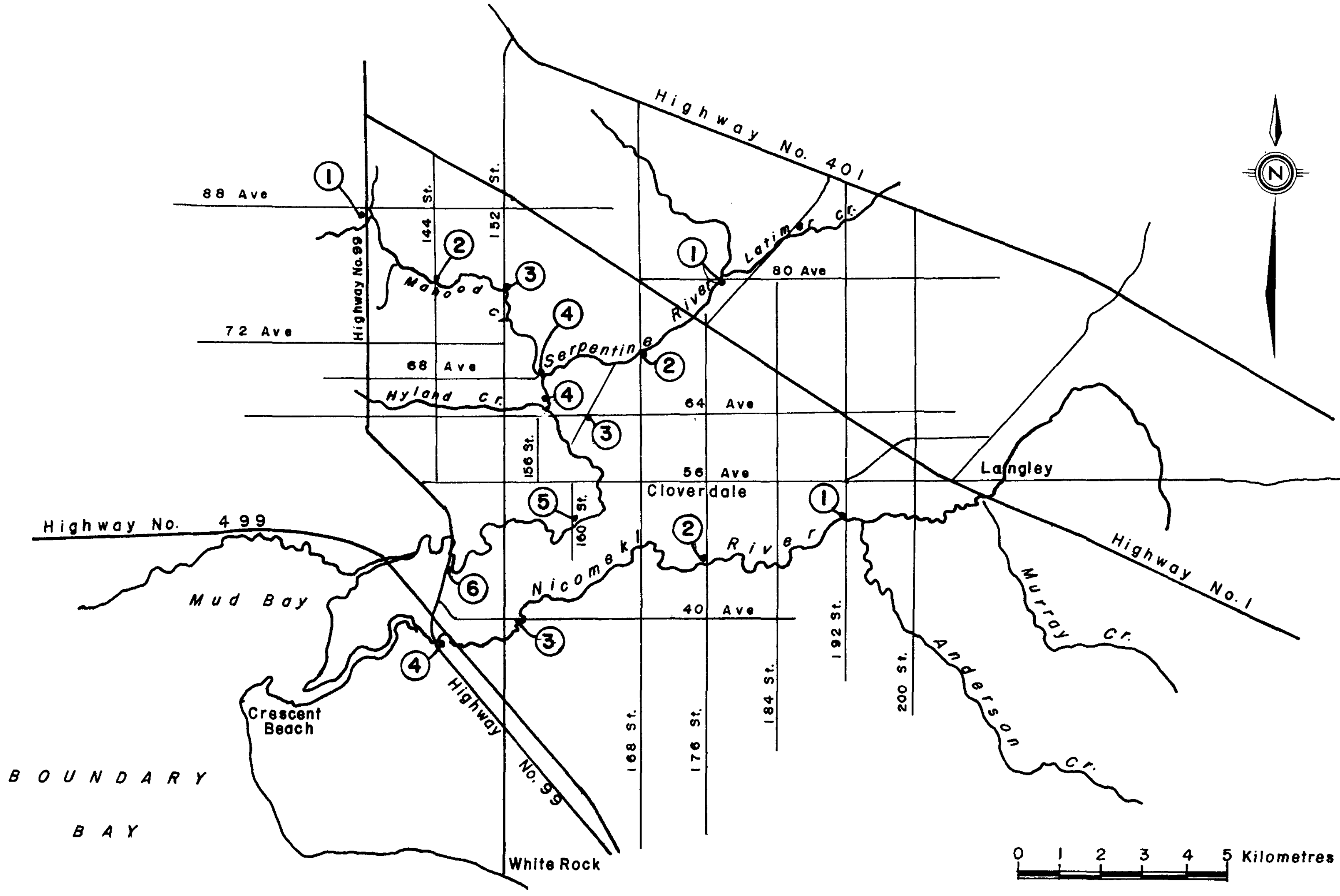

FIGURE 2 SAMPLING STATIONS ON THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK

1.1 Climate, Precipitation

Climate of the region is classed as modified maritime with overcast, wet, mild winters and drier, warm summers. Precipitation, primarily rain, averages 1200 mm annually in the lowlands and 1400 to 1500 mm in the upland headwaters (Table 2; Atmospheric Environment Service, 1972). One hundred to 200 mm of rain falls in 15 to 21 days each month from October to May, but this decreases by July to 30-38 mm of rain over seven days. Snowfall is generally light, contributing just 4% of the total precipitation in the area. Mean daily temperatures vary only 16°C ranging from 2°C in January to 17°C in July. The minimum mean daily temperature is -1°C in January while the maximum is 23°C in both July and August (Table 2).

1.2 Stream Flows

Stream flows in the Serpentine-Nicomekl watershed are extremely variable and highly dependent on precipitation and consequent runoff in the immediate area. No data is available on the total discharge of each river. However Water Survey of Canada has recorded water levels in Mahood Creek and in the Nicomekl River immediately below the confluence of Murray Creek. This data was tabulated by Hirst et al. (1979) and is presented in Appendix I. During the wet winter, flows are extremely variable from year to year. In January, the wettest month, flows ranged from 1 to 4 m^3/sec in Mahood Creek and 2.5 to 7 m^3/sec in the Nicomekl River (Appendix I, Figures 1I and 2I). During the drier months of July and August, flows were generally less than 0.2 m^3/sec, and in Mahood Creek, flows ceased for brief periods when half the summers recordings were made. Locals report that in late summer flows often cease in sections of all the tributary streams, while in winter, flash floods are common. Such fluctuating water regimes can limit fish productivity and will worsen with increased agricultural and urban development.

The winter runoff rate in the tributaries and upland portion of the watersheds is much higher than in the lowlands, partly because

TABLE 2 PRECIPITATION AND TEMPERATURE RECORDS FOR SITES IN THE SERPENTINE AND NICOMEKL WATERSHEDS[1]

Parameter	Location[2]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Mean monthly precipitation (mm)	Kensington Prairie	166	137	101	80	55	50	30	45	71	144	167	188	1234
	Langley Prairie	198	159	123	103	73	67	38	52	91	177	200	222	1500
	Surrey Newton	196	149	117	87	62	54	32	52	81	171	189	199	1389
Maximum rainfall in 24 hr (mm)	Kensington Prairie	74	65	44	42	29	27	33	39	53	59	90	61	90
	Langley Prairie	118	58	52	53	29	38	40	34	57	60	97	85	118
	Surrey Newton	107	52	50	39	28	25	28	29	61	51	71	65	107
Mean daily maximum temperature °C	Surrey Newton	5	8	10	13	17	20	23	23	20	15	9	6	14
Mean daily minimum temperature °C	Surrey Newton	-1	< 1	1	4	6	9	10	10	8	5	2	< 1	5
Mean daily temperature °C	Surrey Newton	2	4	6	8	12	14	17	16	14	10	6	3	9

[1] Data compiled by Atmospheric Environment Service, Canada, Department of the Environment (1972; 1973).

[2] Kensington Prairie represents the lowland agricultural area of the watershed, while Langley Prairie is in the upland of the Nicomekl system and Surrey Newton is in the upland of the Serpentine system.

of higher elevation and a greater ratio of rainfall to surface area drained, but also because of differences in subsoil and land use. The upper portions of each watershed are underlaid by stratified glacio-marine deposits while the lowlands west of Cloverdale are underlaid by fluvial deposits consisting of silty fluvial deposits on top of a sandy layer (Lands Directorate, 1977). In the central and south-eastern portion of the lowland floodplains, organic deposits, particularly peat, blanket the silt deposits. Soil types have been mapped in detail by Sprout and Kelly (1961) and are summarized in Appendix I Table 2I.

1.3 Land Use

Mahood and Hyland Creeks rise in the urban area of northwest Surrey and flow first through single-family residential areas and hobby farms in the upper reaches, then through small intensive farms in the lowland reaches. The Serpentine itself also arises in the urban area but runs primarily through small acreages in the upland then larger farms in the lowland. Latimer Creek also drains primarily small acreages. The Nicomekl and its major tributaries, on the other hand, all begin in agriculturally zoned land and flow through 9 to 15 km of pastures, forage crops and woodlands before entering the urban core of Langley City and Municipality. Some of the small tributaries at the head of the Nicomekl drain land to the east of 232 Street which is designated for future urban growth in the 1979 Official Regional Plan (Figure 3). West of Latimer Road (192 St.), the Nicomekl again flows through farmland to its mouth.

A detailed analysis of specific types of land use is not available for the entire Nicomekl-Serpentine watershed, but the Greater Vancouver Regional District did provide figures for most of the watershed within Surrey and this is presented in Appendix I Table 3I. From the GVRD data, information from the Langley City Planner (T. Tanner, personal communication) and from the 1979 Langley Municipality Official Community Plan, we estimate that roughly 57% of the combined watershed is rural in

(ii) channelization of upland tributaries;
(iii) vandalism of fish;
(iv) removal of stream bank vegetation and consequent increases in water temperature;
(v) increased erosion and sedimentation;
(vi) sewage contamination of streams from septic tank leakage - resulting in increased nitrogen and phosphorous levels;
(vii) increased bacterial contamination from human and pet wastes;
(viii) toxic leachates from garbage disposals;
(ix) increased levels of oils, lead, pesticides and other contaminants in stormwater and road runoff; etc.

1.4 Fish and Wildlife Capability

The natural character of the Serpentine and Nicomekl Rivers has already been severely altered by man's activities. The Nicomekl has been dyked downstream of its confluence with Murray Creek and the Serpentine has been dyked to its uplands south of 88 Avenue. The lowland portions of the main rivers and their tributaries have also been intensively dredged and channelized to serve as drainage ditches for the surrounding farmland. In most cases where the land is farmed, the banks have been stripped of trees and shrubs and cattle have been allowed to graze along the shores. The banks are thus constantly eroding and the water in these sections is usually quite turbid and the bottom covered in deep mud and silt. Neither the mainstem Nicomekl or Serpentine could be considered adequate for salmonid spawning. However, the major tributaries, particularly Anderson, Murray and Mahood Creeks, still have sections suitable for spawning and rearing salmonids. Anderson and Murray Creeks have about 15 and 20 km respectively of good fish habitat with adequate sections of pools and gravel riffles and some sections with tree or shrub cover along the banks. The best areas are ravines which are unsuitable for housing or agriculture and which consequently remain well treed with stable banks and good gravel riffles. Mahood, the major tributary of the Serpentine system, has approximately 7 km of poolgravel riffle-glide sections suitable for spawning and rearing fish, as well as stable, well treed or shrubbed banks. Latimer and Hyland Creeks also have long stretches with good bank cover but their silt bottoms seem unsuited for salmonid spawning, though rearing fish were trapped by Hirst (1979) throughout both systems. At the present time, the major limitations to fish productivity in all the tributaries are siltation of the bottom gravels and low flows in late summer when many of the streams are reduced to a series of standing pools. These conditions can be expected to worsen with future development unless mitigated.

Spawning records show that coho salmon (Oncorhynchus kisutch) have numbered anywhere from 75 to 7500 in the Nicomekl and 75 to 3500 in the Serpentine River between 1947 and 1976 (Marshall et al., 1979). Fewer than a thousand coho spawned each year from the late 1950's to 1969 (except in 1961 and 1964) but since 1970, 1500 to 3500 fish have been estimated each year in each system. Steelhead (Salmo gairdneri) and cutthroat trout (Salmo clarki clarki) also spawn in these rivers but their numbers are unknown. Electroshocking done by Environmental Protection Service staff in 1972 and 1973 found, in addition to salmonids, three-spined stickleback (Gasterosteus aculeatus), prickly sculpin (Cottus asper), redside shiner (Richardsonius balteatus), lamprey (Lampetra richardsoni), brown bullhead (Ictalurus nebulosus), peamouth chub (Mylocheilus caurinum), and crayfish and frogs.

Great blue heron (Ardea herodias) feed in the rivers and channels of the lowlands, and ducks, particularly mallard (Anas acuta), pintail (A. platyrhynchos), and widgeon (A. americana) feed in adjacent flooded fields and in Mud Bay. Numerous other species of waterfowl nest or overwinter in Mud Bay.

Mud Bay was once the source of 60% of British Columbia's shellfish industry but the fishery was closed in 1962 due to fecal contamination from rivers and outlets draining into the Bay (Kay, 1976) However, the Bay is still an important saltmarsh-eelgrass-mudflat area for feeding waterfowl and fish such as juvenile salmon and herring, and productivity could suffer if water quality in the rivers decreased further.

Accordingly, in spring 1974, EPS established stations on the mainstem Nicomekl and Serpentine Rivers and on Mahood Creek and began a program of regular sampling for 16 routine water quality parameters as well as bottom macroinvertebrate populations, periphyton populations and chlorophyll-a and phaeopigment content, and levels of various metals and calcium in fish flesh. This report presents the results for samples collected from June 1974 to November 1975.

2 METHODS

2.1 Sample Site Locations

Sampling sites were chosen along the length of the Serpentine and Nicomekl Rivers and Mahood Creek to show whether there was a cumulative effect of agricultural and urban runoff on water quality. Four sample sites were established on the lower Nicomekl, six on the Serpentine and four on Mahood (or Bear) Creek as shown in Figure 2. Sites 1 and 2 on Mahood Creek represent flow through an urban area while the remaining sites were in the lowland agricultural areas of the watersheds. Stations on the Nicomekl and Serpentine and station 4 on Mahood Creek had grass banks and mud-silt bottoms. Stations 1 to 3 on Mahood Creek had gravel bottoms and dense bank cover of deciduous trees and shrubs.

2.2 Water Quality

Water samples were collected from the Serpentine and Nicomekl stations once a month in June and July, 1974, then once every two months until January 1975 when samples were again collected once a month until November 1975. Sampling frequency was the same for Mahood Creek except that sampling here did not begin until November 1974. Each month stations were sampled in one day from 08:30 hr to 14:30 hr in the following sequence: beginning at station 1 on the Nicomekl, proceeding downstream to station 4; then working from station 6 on the Serpentine upstream to station 1; finally, sampling Mahood Creek beginning at station 4 and going upstream to station 1. Water was collected in a plastic pail in midstream at the surface, then divided into small glass or plastic bottles and preserved according to the requirements of the analyses to be done (see Appendix II). Samples were kept in a cooler of ice and taken the same day to the Department of Environment - Fisheries and Oceans Laboratory at Cypress Creek, West Vancouver, for analysis. At each site pH was measured using a Hach kit[1] colorimetric technique and stream temperature was recorded.

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[1] Hach Chemical Company. Box 907, Ames, Iowa. 500100 USA.

In the laboratory, water samples were analyzed for dissolved oxygen content; total, volatile and non-filterable residues; colour, turbidity, total hardness, alkalinity, conductivity, and levels of nitrite-nitrate nitrogen, ammonia nitrogen, total phosphate and total organic carbon. Methods used for these analyses are listed in Appendix II.

Oxygen content of the rivers over a 24-hour period was measured once. Beginning at 2330 hr on August 6, 1974, dissolved oxygen was measured every two hours for a 24-hour period at all stations on the Serpentine and Nicomekl Rivers.

Coliform levels at each station were measured in March and August, 1975, but the results of these tests were accidentally destroyed. The GVRD has routinely measured coliform levels in this watershed but have agreed with the municipalities not to publicize the results. Coliform levels from the GVRD survey may, however, be viewed at the Langley and Surrey municipal offices.

2.3 Macroinvertebrate Populations

Macroinvertebrate populations were sampled at each station in October 1974 and January, April and July 1975, but because funds were limited, only the April samples were analyzed. An Eckman dredge[2] with a collection capacity of 529 cm^2 was used to sample bottom sediments at the Serpentine and Nicomekl stations. These samples were sieved on site through a 520 u sieve. However the bottom of Mahood Creek was too compacted for the Eckman dredge so a modified Hess circular sampler[3] with a collection area of 0.093 m^2 and a 351 u net was used. The Hess sampler could not be used in the Serpentine or Nicomekl because these rivers were too deep.

Three samples were taken at a site and the material pooled prior to analysis. Samples were preserved with a buffered 10% formalin

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[2] Wildco Instruments and Aquatic Sampling Supplies, Saginaw, Michigan, U.S.A.

[3] Built by EPS staff as described by Waters and Knapp (1961).

solution and later identified and enumerated at the Environmental Protection Service Laboratory, 1801 Welch Street, North Vancouver.

Organisms were categorized as to their sensitivity to pollution; i.e., "pollution tolerant", "moderately tolerant", or "sensitive" according to Servizi and Burkhalter (1970) and the numbers in each category were graphed. Families in each category are listed in Appendix III. No attempt was made to compare the results of the two collection methods; so data for Mahood Creek must be considered separately from data for the Serpentine and Nicomekl.

2.4 Periphyton Populations, Pigment Content and Dry and Ash Weight

Periphyton was collected on glass microscope slides immersed at each station. Slides were changed once a month from March 1975 to November 1975 except in July and August when the slides were changed twice a month. At each site, six slides, each 19.6 cm^2 in area, were mounted on a plexiglass tray and suspended 25 cm below the water surface from a float anchored by a concrete block (Stockner et al., 1972). The contents of two slides per site were analyzed for chlorophyll-a and phaeopigment content, two were used to determine dry and ash weight, and two were used to identify and enumerate the kinds of algae present. Slides were selected at random for each analysis. For determinations of pigment or ash weight, 2 slides were scraped into 125 ml of distilled water and refrigerated. Samples for species identification were scraped into a 500 ml glass bottle of distilled water containing 1 ml of Lugol's solution. Pigment content and dry and ash weight analyses were done by the Department of Environment - Fisheries and Oceans Laboratory at Cypress Creek as outlined by Strickland and Parsons (1968). Algae were identified under an inverted microscope using Prescott (1964) as a key. The number of cells of each genera was counted in two fields, averaged, then extrapolated to give the number of cells per square centimeter of slide surface.

Because of vandalism, no samples could be collected from Mahood Creek, stations 1, 5 and 6 on the Nicomekl or station 1 on the Serpentine.

Due to funding shortages, pigment and ash weight were determined for only four months and algae identification and enumeration done for only June or July samples.

2.5 Metal Levels in Fish Muscle Tissue

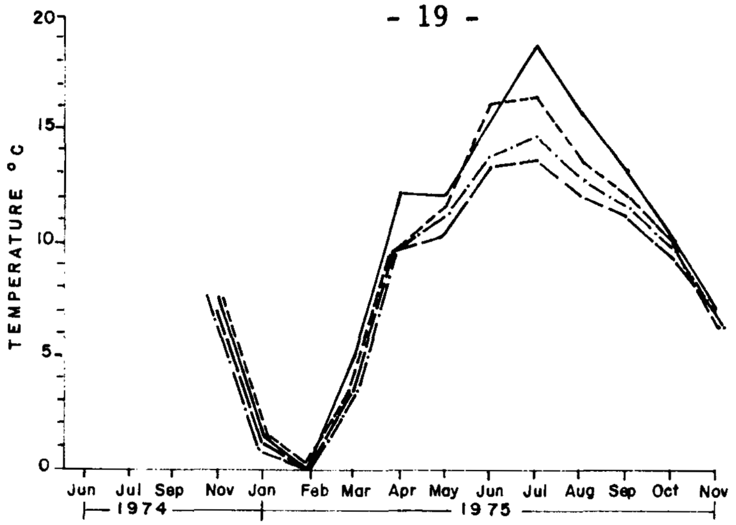
During July and August 1975, fish were caught at each station using a minnow trap. Over the two month period a maximum of ten fish were kept at any one station. On the day of capture the fish were weighed, measured for length, then a section of muscle tissue was taken from each fish by one of two methods: for large fish, a rectangular section of flesh approximately 30 grams in weight was removed from one side of the fish immediately behind the head between the mid dorsal and lateral lines; in smaller fish, a 3 centimeter section of the entire fish body was removed from between the pectoral and anal fins. In each case only the muscle tissue was dissected out and frozen for analyses. Tissue samples were later analyzed for calcium, magnesium, copper, zinc, iron and manganese by the EPS - Fisheries and Oceans Laboratory at Cypress Creek. Both the wet (acid) method and the low temperature, dry ash methods were used as described in the 1974 Laboratory Manual published by the Laboratory. Since a minimum sample size of 75 grams was required for these routine metal analyses, muscle sections from fish of the same species were pooled until an adequate sample weight was acquired for each site.

3 RESULTS AND DISCUSSION

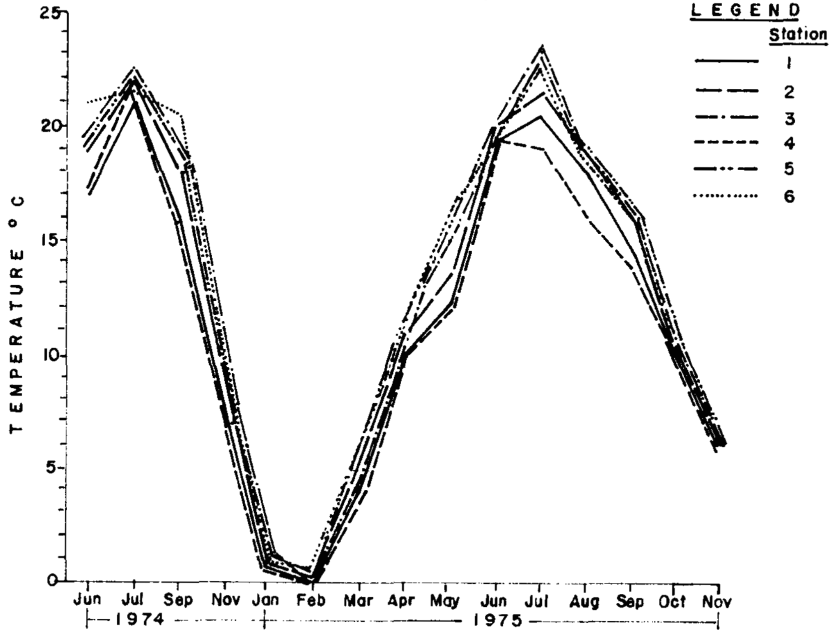
3.1 Water Quality

3.1.1 Temperature. Water temperature recorded for the Nicomekl and Serpentine Rivers and Mahood Creek are shown in Figure 5. Water temperatures correspond closely to average air temperatures for the region (Table 1) ranging between sites from a low of -0.5°C - 0°C in February to a high of 16.2°C - 23.5°C in July. Differences in water temperatures between sites was greatest in the summer months and reflect differences in vegetative shade cover and, to a lesser extent, depth and stream flows. The Serpentine River which has very little shade cover anywhere along its banks had the highest summer temperatures of up to 23.5°C, while Mahood Creek which is shaded over much of its course did not exceed 18.5°C. Stream temperatures in the Nicomekl increased progressively from upstream to downstream stations as the river bank cover changed from bush and trees above station 1, to primarily grass or dirt through the urban, then rural sections downstream. Even on Mahood Creek, which is generally well shaded, bank cover at a particular site affected stream temperatures at that site: station 1 in the urban section and station 4 in the rural area both have grass banks and both had higher summertime temperatures than the well treed middle stations.

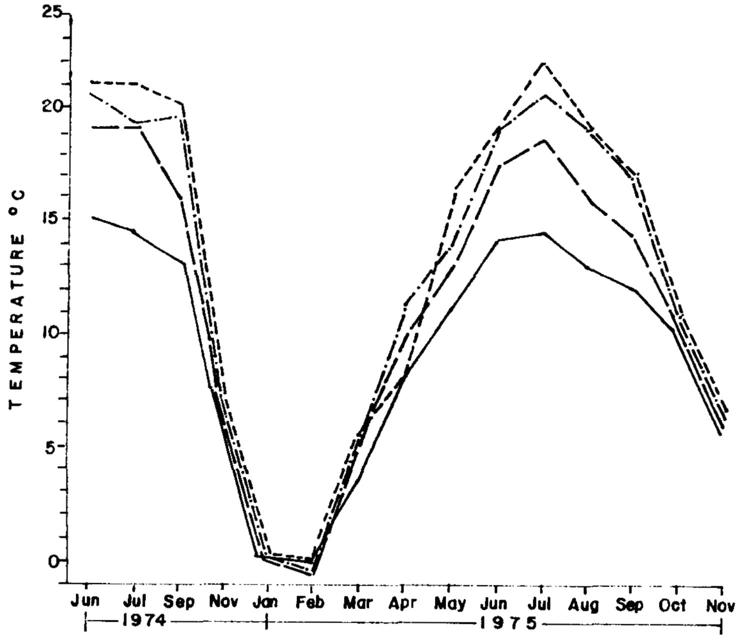
The incipient lethal temperature for coho fry is 25.0°C (Brett 1952), for stickleback it is 25.8°C (Blahm and Parente, in Water Quality Criteria, 1972), and for wild adult steelhead it is 21°C (Coutant, 1970). Thus from mid June through August, salmon and trout fry or early adult spawners would be faced with near lethal temperatures if they migrated from the cooler tributaries or estuary into the mainstem Serpentine or Nicomekl Rivers. Even in the tributaries, growth may be inhibited in resident salmon, trout, stickleback, and invertebrates if stream temperatures climb above 19°C as a result of low flows and local removal of shoreline vegetation (Brett, 1971). High water temperatures can also promote excessive growth of algae and eventual eutrophication, particularily where nutrient levels are high (Quality Criteria For Water, EPA, 1976).



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 5. WATER TEMPERATURES RECORDED AT STATIONS ON THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

3.1.2 Dissolved Oxygen. The dissolved oxygen content (mg/l O_2) of samples taken from the Nicomekl and Serpentine Rivers and Mahood Creek are given in Figure 6, while oxygen saturation levels are shown in Figure 7.

In Mahood Creek, where salmonid spawning is likely, dissolved oxygen content always exceeded 7 mg/l and saturation levels were usually 90% or greater and never less than 80%. Corresponding with seasonal temperatures, oxygen content at all stations was higher in the winter months from November to April and decreased in the summer months as stream temperatures rose. Saturation levels peaked at all stations in April 1975 (101-136%), then gradually declined until October when the lowest levels of 71-88% were measured. Oxygen levels at the downstream station were usually lowest while values at the upstream station 1 were generally highest and supersaturated from March until September.

In the Nicomekl, as in Mahood Creek, oxygen content was always above 7 mg/l, and saturation levels were lowest in the cold wet months from November to March. Saturation levels in the winter usually ranged from 65 to 85%, somewhat lower than samples from Mahood Creek. However from June to September both years, and in April (but not May) of 1975, the Serpentin was almost always supersaturated, with peak levels recorded in September. Unlike in Mahood Creek, saturation levels in the Nicomekl tended to increase downstream from station 1. This trend, however, was only evident during spring and summer when the water was supersaturated with oxygen.

In the Serpentine River, oxygen saturation levels were lowest at the two upstream stations and highest at the two downstream stations. As on the Nicomekl, this interstation trend was only obvious during the summer months when saturation levels were reached. Seasonal differences in oxygen saturation were not as marked on the Serpentine as in the Nicomekl but the pattern of change was similar with lowest values recorded in the fall and winter and highest values from June to September, and with a slight peak in April and maximum levels reached in September. Saturation levels at the upstream two stations were usually quite low

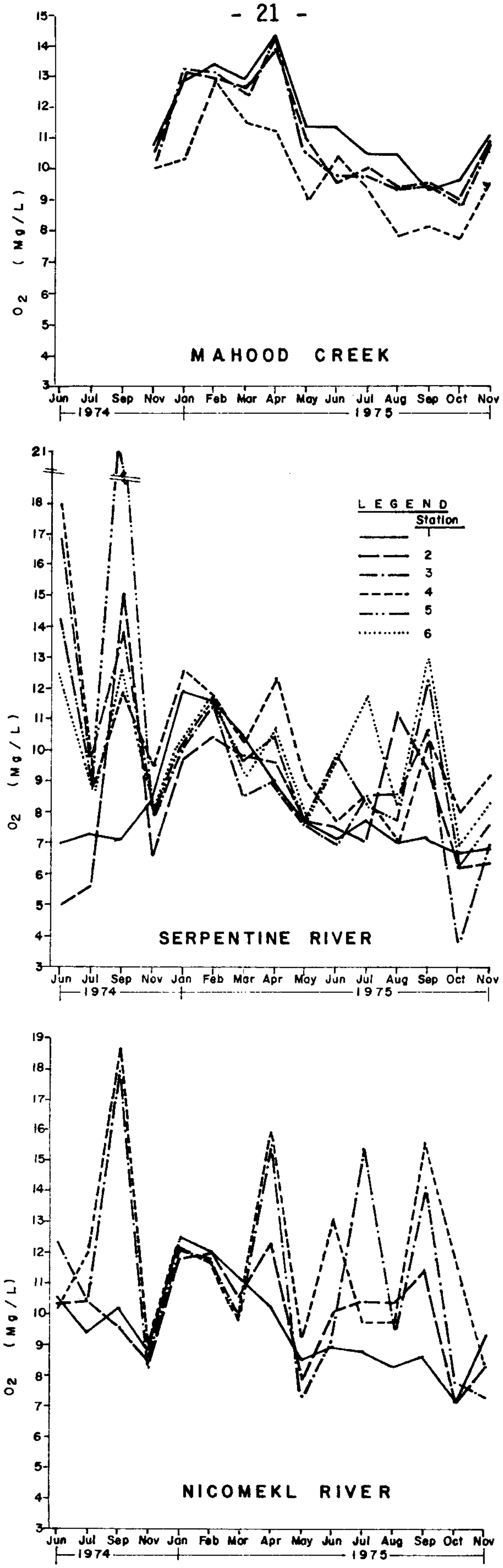
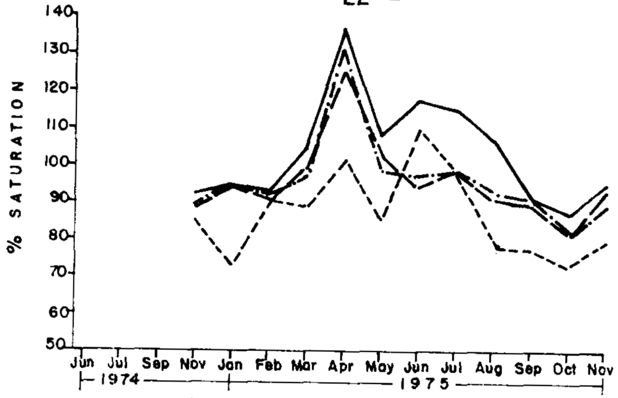
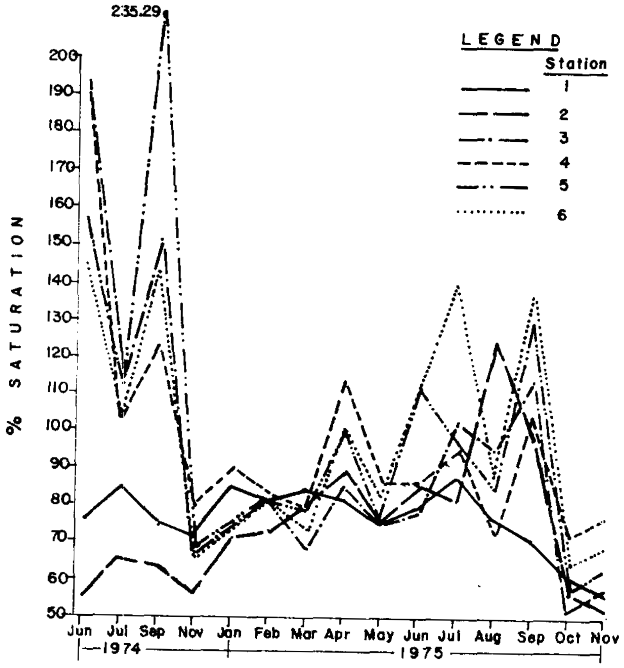


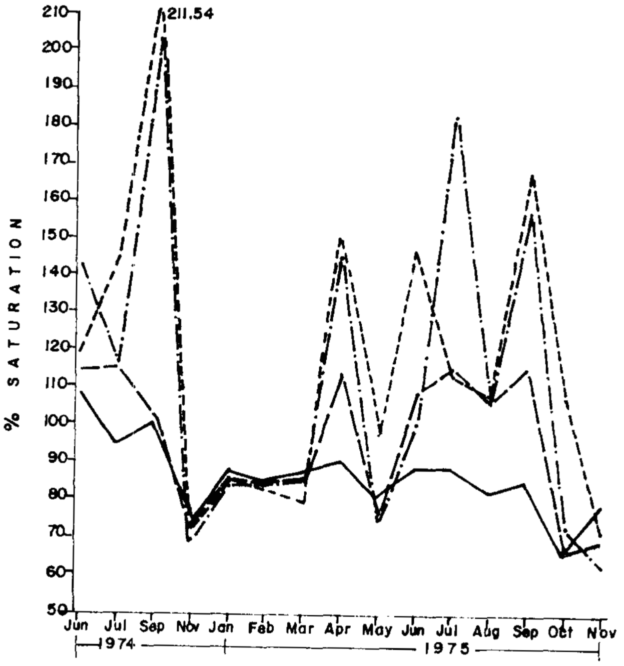
FIGURE 6. DISSOLVED OXYGEN CONTENT OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 7. OXYGEN SATURATION OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

ranging from 55-85% throughout the year although station 2 was supersaturated in August and September 1975. Downstream, winter levels ranged usually from 67-85% while summer levels were from 102-235% in 1974 and 75-136% in 1975.

Oxygen supersaturation in the downstream lowland stations of the Serpentine and Nicomekl could be a by-product of algae stimulated to growth by the warmer temperatures and increasing daylight of spring, and fed by nutrient rich runoff from adjacent fields. Measurements of oxygen recorded over a 24-hour period in the Nicomekl and Serpentine confirm that saturation levels varied with light levels: oxygen saturation levels declined after sunset reaching a low just before daylight, then increased through the day and peaked in the afternoon (Figure 8). However in August when these 24-hour measurements were made there were no obvious differences in the daily pattern between upstream and downstream stations.

Given the relationship of oxygen saturation levels to light levels, the trends found in routine monthly samples showing a downstream increase in saturation of the Nicomekl and an upstream increase in Mahood Creek could be due to the order in which these stations were sampled, except that the Serpentine, which was sampled in the same fashion as Mahood Creek, shows the same trend as the Nicomekl which was sampled in the reverse order. Thus we feel the trends found would have been present regardless of sampling order although sampling order must have affected values somewhat.

Although in the summer months fish production, indeed survival is limited by the high temperatures in the mainstem Nicomekl and Serpentine, in the winter months, low oxygen levels could decrease productivity of susceptible fish and invertebrate species, particularly in the mainstem Serpentine. On the basis of a review by Doudoroff and Shumway (1970) on the effects of oxygen concentration on fish, the U.S.A. Enviromental Protection Agency (Water Quality Criteria, 1972) recommend that for maximum productivity, especially of salmon eggs, maximum natural

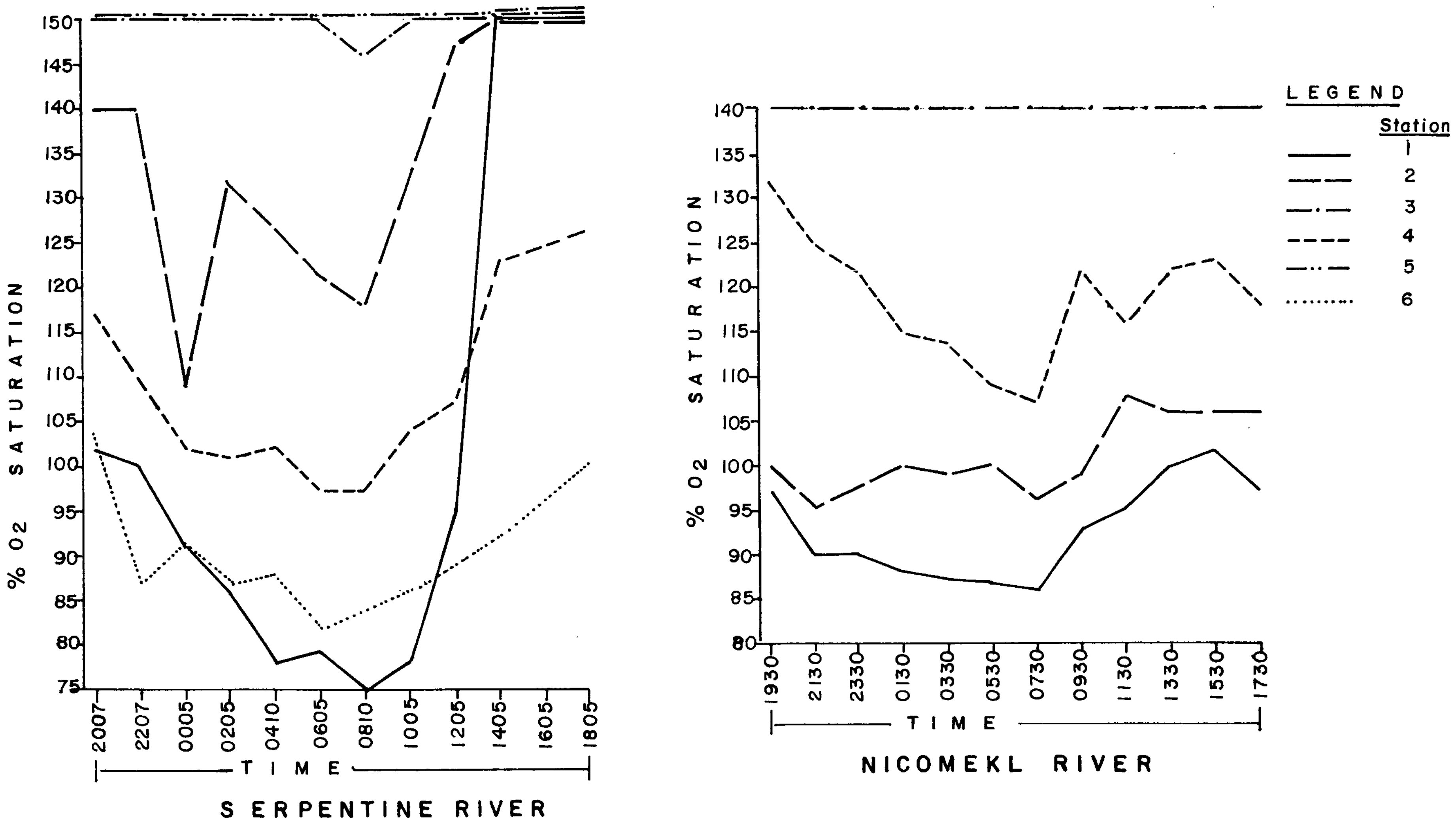


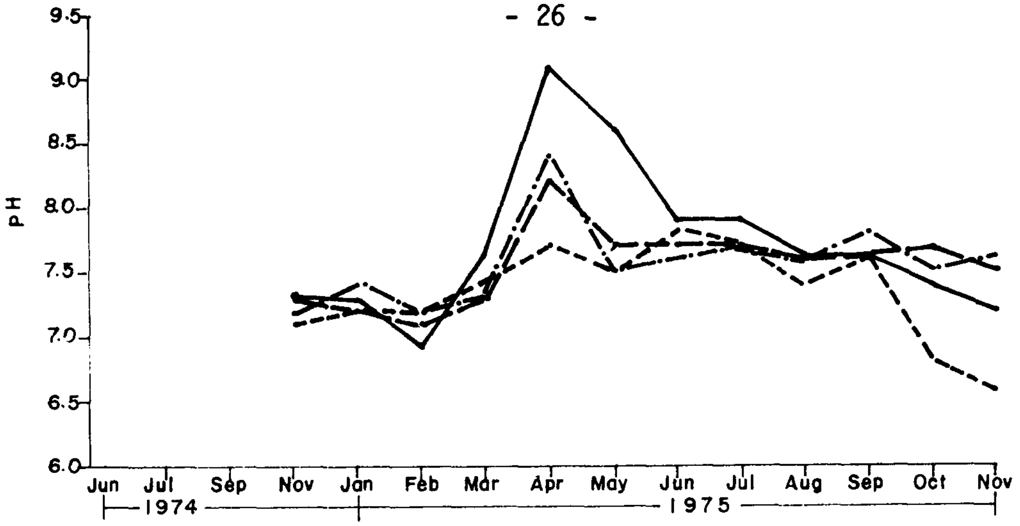
FIGURE 8. OXYGEN SATURATION OF WATER SAMPLED OVER A 24 HOUR PERIOD FROM THE NICOMEKL AND SERPENTINE RIVERS ON AUGUST 6, 1974

saturation levels should be maintained - assumming that if man has not altered the system, natural saturation levels would be 100%. Thus of the streams studied, only Mahood Creek had acceptably high winter oxygen saturation levels and even here saturation often dropped below 100%, particularly near the mouth. If maximum egg to juvenile production is to be maintained in such tributaries, oxygen saturation levels in midstream and in gravel beds should not be allowed to decline any further. Thus construction or other activities which result in oxygen depletion or stream bank erosion and silt deposition in gravel beds should be discouraged.

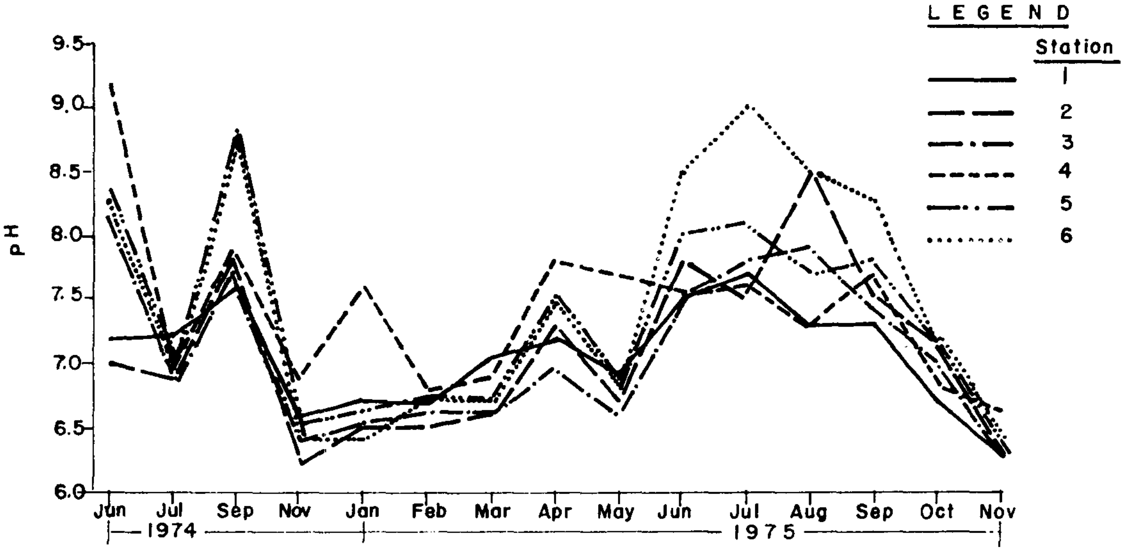
3.1.3 pH. pH values varied distinctly from season to season in the Nicomekl and Serpentine (Figure 9). Values were low and stable from November through March then high and variable from April until September. Like oxygen levels, pH values increased proceeding downstream, but only during the spring and summer months.

In Mahood Creek, pH values were only marginally greater in summer samples although a distinct peak was measured in April. Unlike pH levels in the mainstem rivers, the highest pH values in Mahood Creek were recorded at the upstream station. This pattern corresponds with interstation differences in oxygen saturation levels.

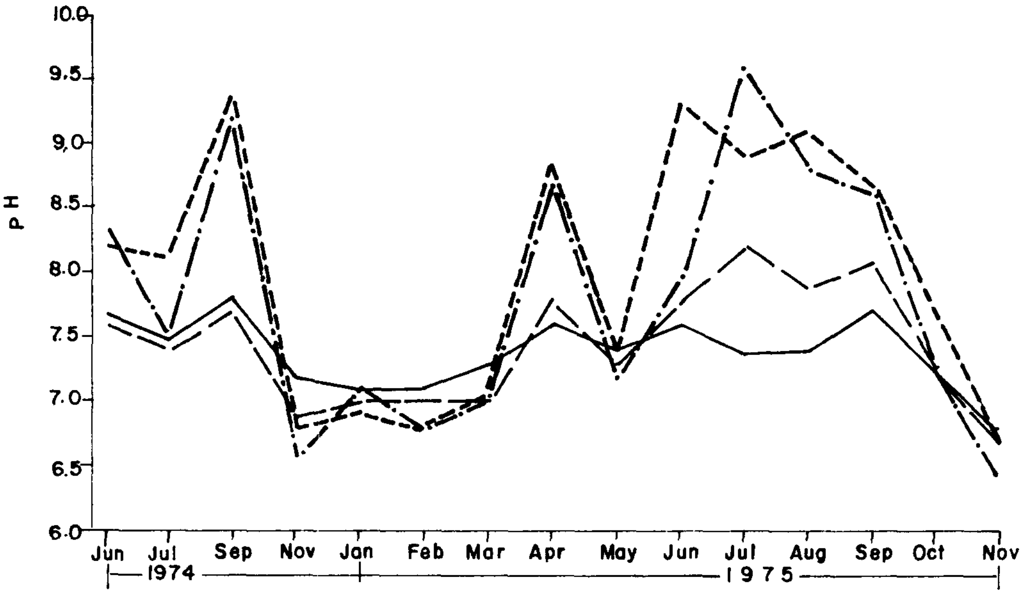
pH values at the downstream stations of the Serpentine and Nicomekl and at the upstream station on Mahood Creek peaked at 9.1-9.3 which is above the 1972 E.P.A. levels recommended for maximum protection, and approaches the tolerance limits of some salmonids (Water Quality Criteria, 1972). However pH levels were more commonly within the best acceptable range of 6.5 to 8.5. The very high levels recorded in summer correspond with extremely high oxygen levels and are probably a result of high rates of photosynthesis altering the carbonate buffering capacity of the water.



MAHOOD CREEK



SERPENTINE RIVER

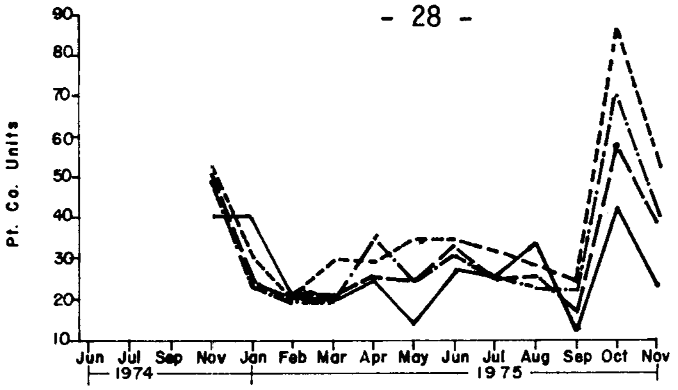


NICOMEKL RIVER

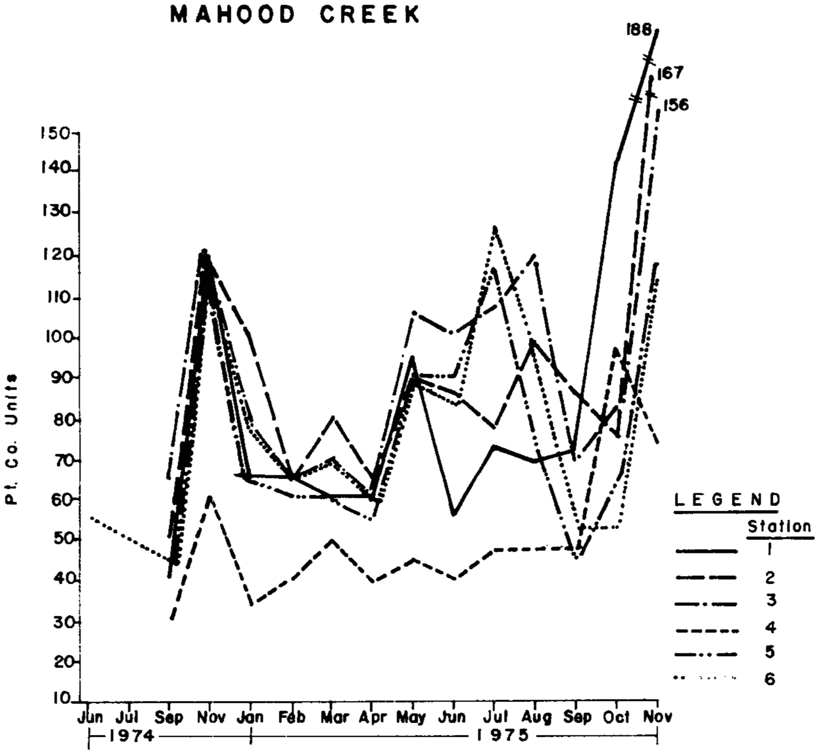
FIGURE 9. PH OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

3.1.4 Colour. In all three streams colour levels peaked both years in October or November, otherwise there were no obvious seasonal or interstation trends common to all streams. In the Nicomekl, colour levels were lowest in the summer months from June to September each year. Throughout the year, samples from stations 3 and 4 were more highly coloured than from the upstream stations 1 and 2 (Figure 10). Samples from the Serpentine showed no consistent summer-winter differences other than the obvious peak in November. Colour levels at station 4 immediately downstream of the mouth of Mahood Creek were always lowest, but at the other stations colour values were highly variable. Colour levels in Mahood Creek were two to three times lower than in the Serpentine and Nicomekl and more stable from month to month. Since there were no known industries contributing to high colour levels on the Nicomekl and Serpentine, the higher colour levels found there were likely a result of the organic runoff from adjacent agricultural operations,and the peak colouring in all streams in November was likely a result of fall rains washing organic material accumulated over the summer into the streams.

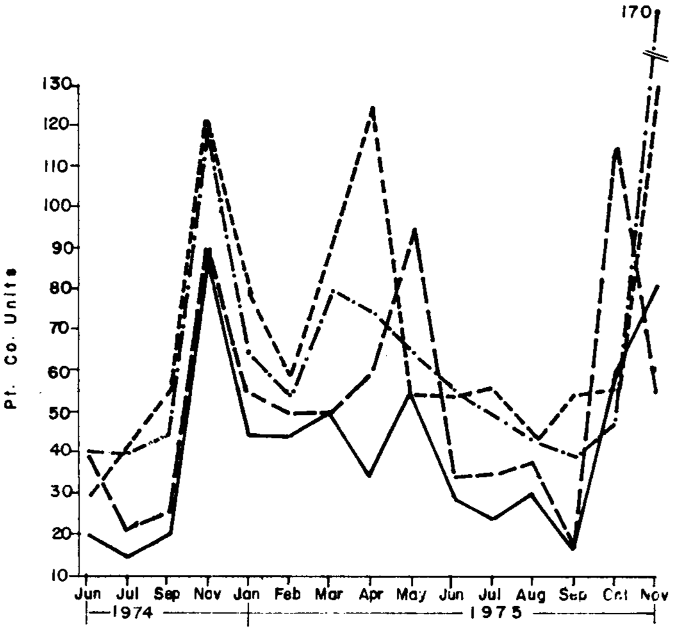
3.1.5 Turbidity. In the Nicomekl, turbidity readings were high from November to February, 1974 and again in November, 1975 but usually low during the spring and summer months (Figure 11). The pattern of turbidity changes in the Serpentine were quite different from the Nicomekl. In the Serpentine, turbidity levels were generally high from June to November both years, with a peak in November 1974, but low from January to March. This pattern was more obvious at some stations than others. Mahood Creek was more similar to the Nicomekl in that turbidity levels peaked in November and February, 1974 and October, 1975 but recordings were generally low the rest of the time. There were no consistent differences in turbidity readings between upstream and downstream stations on any of the streams except on the Nicomekl where station 1 was usually least turbid.



MAHOOD CREEK

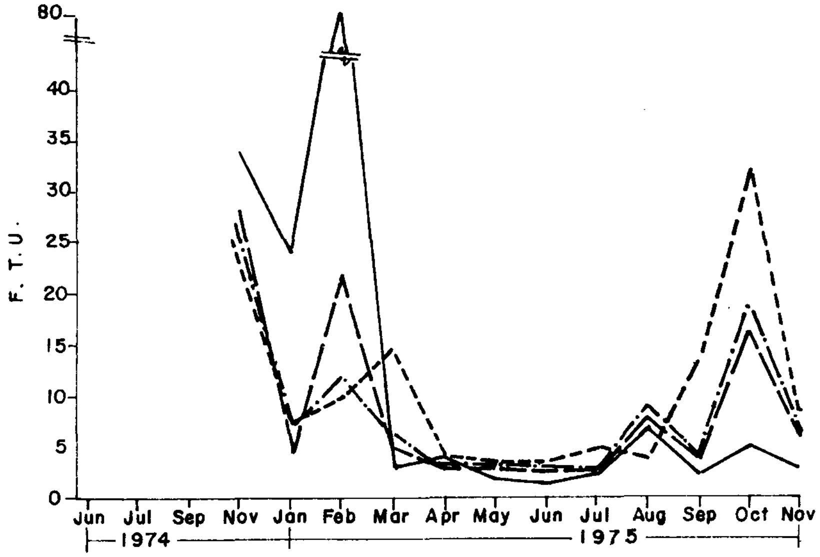


SERPENTINE RIVER

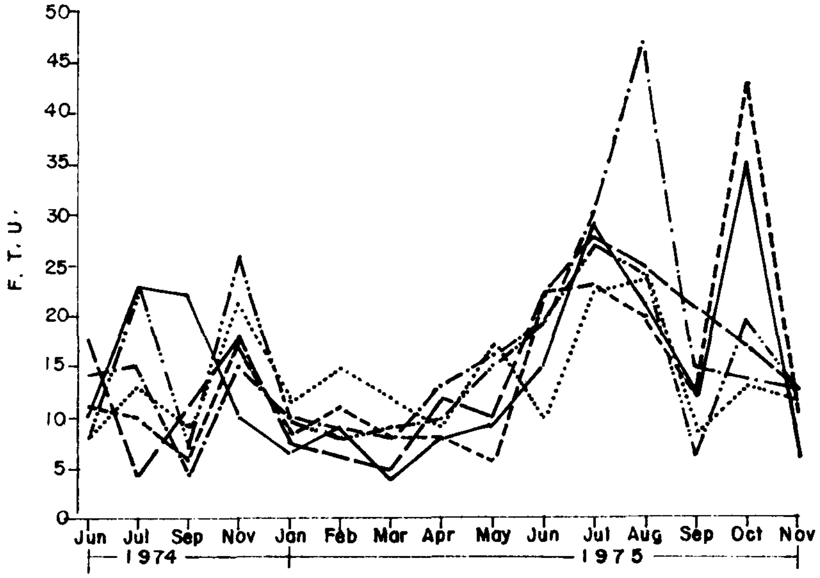


NICOMEKL RIVER

FIGURE 10. COLOUR OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975



MAHOOD CREEK



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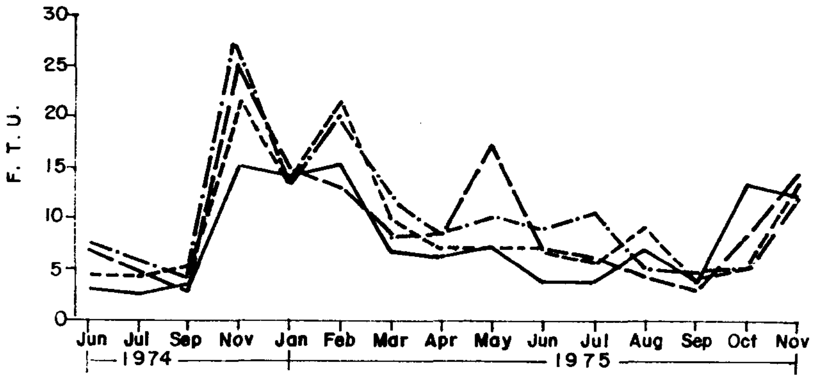


NICOMEKL RIVER

FIGURE 11. TURBIDITY OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

Peak levels in all three rivers were usually in the range of 20 to 30 Formazine Turbidity Units (FTU), high levels were over 15 FTU, and low levels under 10 FTU. High turbidity levels of 34 and 80 FTU which were recorded at station 1 on Mahood Creek during the winter of 1974 resulted from siltation caused by a construction project. Similarly, unusually high levels at one station or another during a period of normally low turbidity readings were probably due to local activities or grazing causing streambank erosion and stream sedimentation. During periods of "low" turbidity, readings from the Serpentine, which ranged from 6-12 FTU, were higher than the average "low" values of 2-8 FTU recorded in the Nicomekl River and Mahood Creek. This difference reflects the fact that much of the Serpentine's banks are barren of brush or trees and therefore more subject to erosion than the banks of the Nicomekl or Mahood. However, the reason for high turbidity levels in the Serpentine but low levels in the Nicomekl and Mahood during the summer is not obvious.

3.1.6 Residue: Total, Non-Filterable, Volatile.

(i) Total Residue. Seasonally the pattern of change in total residues was similar in the Nicomekl and Serpentine (Figure 12). Residue values were high from June until November 1974, then dropped in January, 1975 and remained low until July, then peaked in September and October, but dropped sharply again in November. This pattern of change was slightly different in Mahood Creek as residue levels did not drop in 1975 until March and increased again as early as June (Figure 12).

Residue levels in Mahood Creek ranged from 80 to 283 mg/l and were generally lower than in the Nicomekl or Serpentine where levels ranged from 100 to 7600 mg/l and 95 to 990 mg/l respectively. In both the mainstem rivers there was a marked increase in residue levels found at downstream stations (except station 4 on the Serpentine), while in Mahood Creek, residue levels were highest at the upstream station 1. This to be expected as bank cover was least and activity greatest at these stations

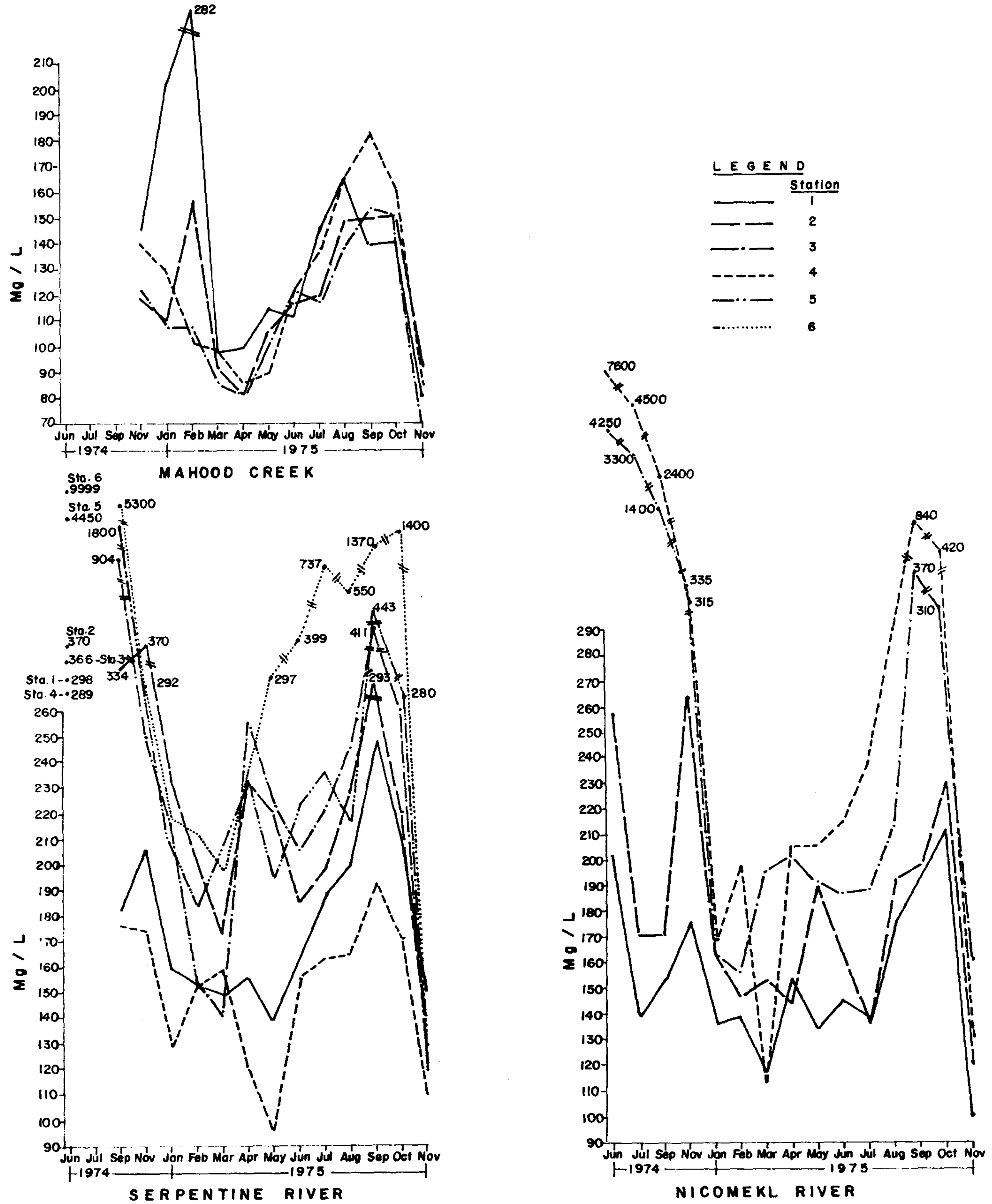


FIGURE 12. TOTAL RESIDUE IN WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

so sedimentation due to erosion and runoff would be high. Low residue values found at station 4 on the Serpentine reflect its position immediately downstream of the mouth of the cleaner Mahood.

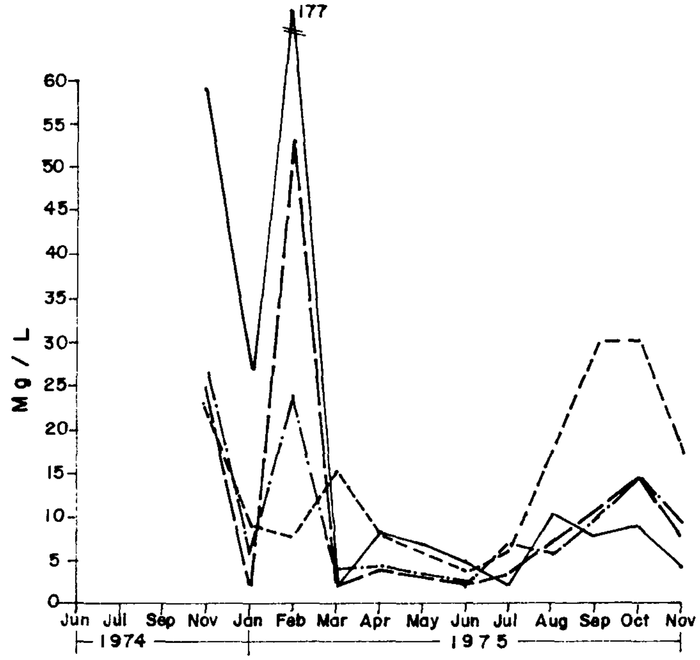
Total residue levels are a measure of combined levels of suspended sediment, algae and other organic components, and dissolved solids in the water column. Seasonal or interstation differences in total residue levels of the different rivers can only be understood by looking at changes in the component parameters.

(ii) Non-Filterable Residue. Non-filterable residue levels are a measure of suspended sediment and organic content in the water column. In the Nicomekl there was a seasonal trend to these values at stations 1 and 2 where levels were high and variable from September to May then lower and more stable in June and July each year (Figure 13). But this trend was not evident at the two downstream stations where levels were slightly higher than at upstream stations and highly variable from month to month. At all stations levels were higher in the fall and winter of 1974 than during the same period in 1975.

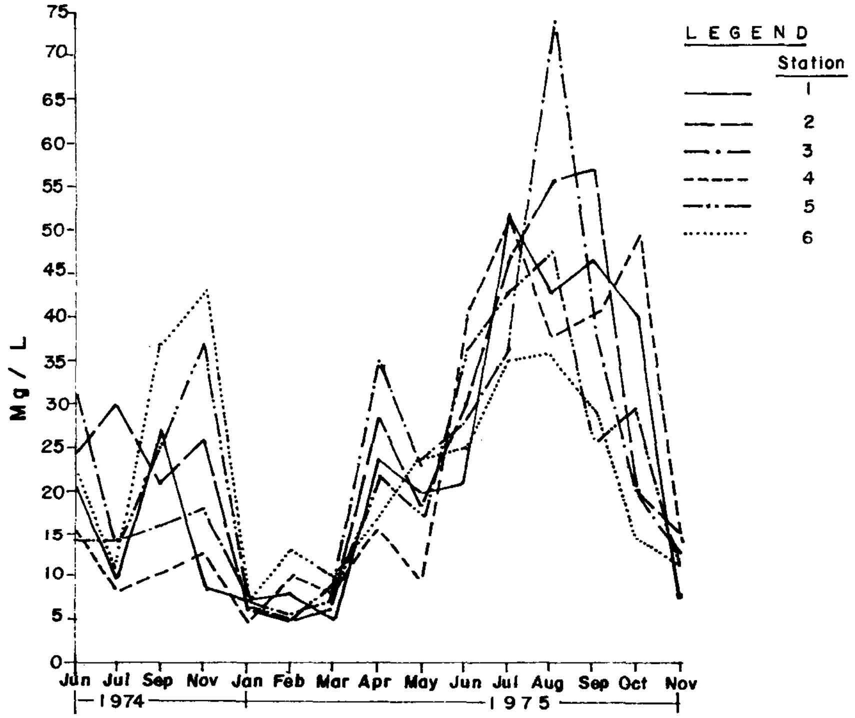
A definite seasonal pattern was obvious at all stations on the Serpentine, but unlike stations 1 and 2 on the Nicomekl, levels were lowest in January, February and March, 1975 and high the preceeding and following summer and fall. This seasonal pattern very roughly corresponds to that of turbidity levels (Figure 11). Nineteen seventy-five values in the Serpentine were generally the highest recorded from the three rivers.

Non-filterable residue levels in Mahood Creek were lower than in the mainstem rivers except in the winter of 1974 when construction above station 1 introduced high levels of suspended solids into the stream. In Mahood Creek, values were low from April through July, then increased from August until October 1975. Readings at station 4 were slightly higher than at upstream stations.

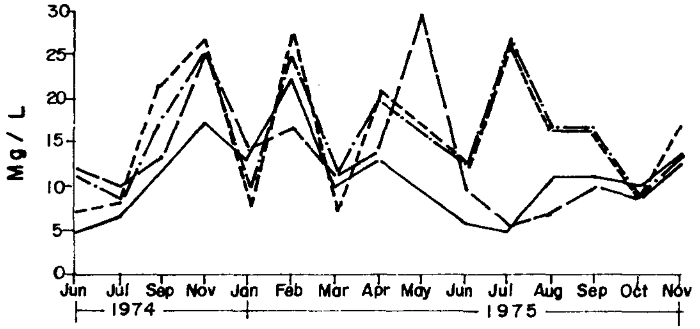
(iii) Volatile Residue. Volatile residue, a measure of the organic component in the water column, was highest in June, 1974 in both the



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

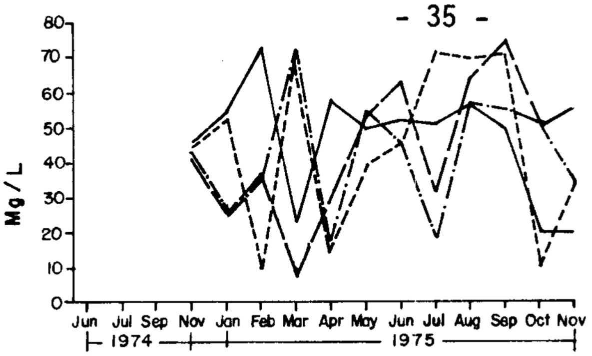
FIGURE 13. NON-FILTERABLE RESIDUE FOUND IN WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

Nicomekl and Serpentine Rivers (Figure 14). Values decreased until January 1975 then remained relatively stable until August or September when organic levels again peaked, but only marginally compared to the previous summer. Downstream stations had much higher levels of organics in the summer of 1974 and to a much lesser extent, in the fall of 1975. There were no obvious seasonal differences in organic levels of water from Mahood Creek (Figure 14), but no measurements were taken in 1974 when these differences were most evident in the mainstem rivers. There were also no consistent differences between stations on Mahood Creek. During the winter, organic levels, though variable, were in the same range in all three streams.

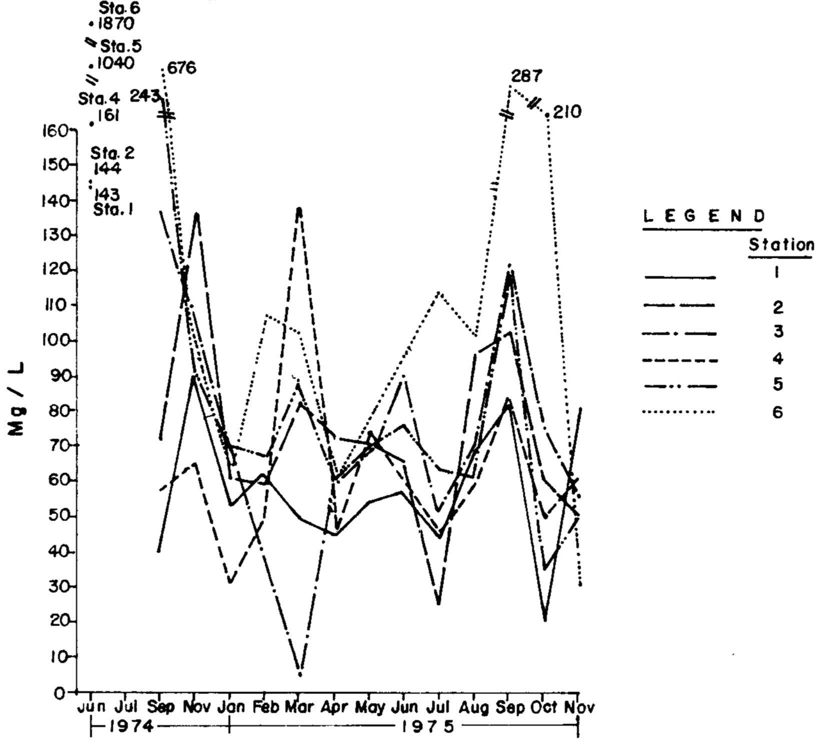
3.1.7 Total Organic Carbon. Organic carbon levels are used as an indication of organic material in the water column which, if present in excess, may decrease dissolved oxygen levels, taint fish flesh, and cause obnoxious odours. Sources of organic material in the streams are usually natural detritus, domestic and industrial waste discharges, and runoff from feed lots, pastures, nurseries, fertilized farm fields and other agricultural operations.

In the Nicomekl, organic carbon levels were usually higher at the two downstream stations located in the intensively farmed lowland (Figure 15). However in the Serpentine, organic carbon levels at all stations, except 4, were as high as or higher than at the downstream stations on the Nicomekl. This would be expected as the entire length of the Serpentine where stations were located was farmed, whereas the upstream stations on the Nicomekl were in a more residential area. Samples from station 4 on the Serpentine had lower carbon levels than elsewhere in this river because water here is diluted by Mahood Creek which always had much lower organic carbon levels than the mainstem rivers.

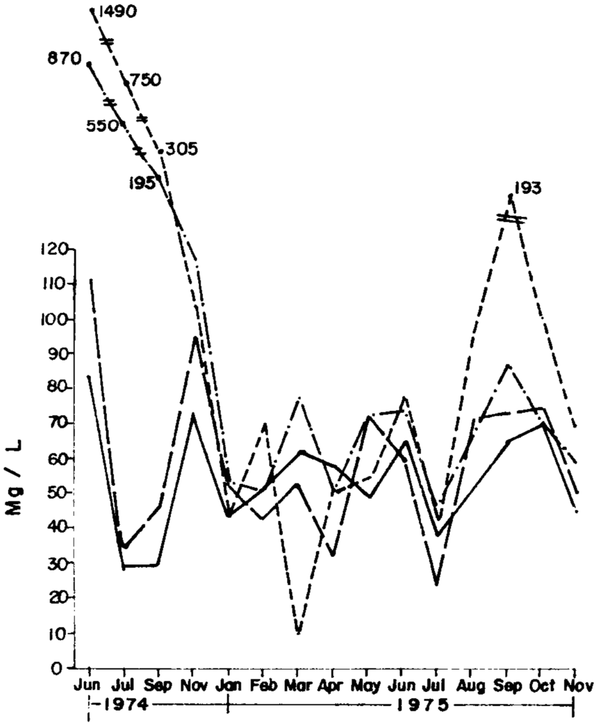
At all mainstem stations, organic carbon levels peaked both years in November with the start of the heavy winter rains. During the dry summer months from June to September, 1975, carbon levels in the



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 14. VOLATILE RESIDUE LEVELS OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

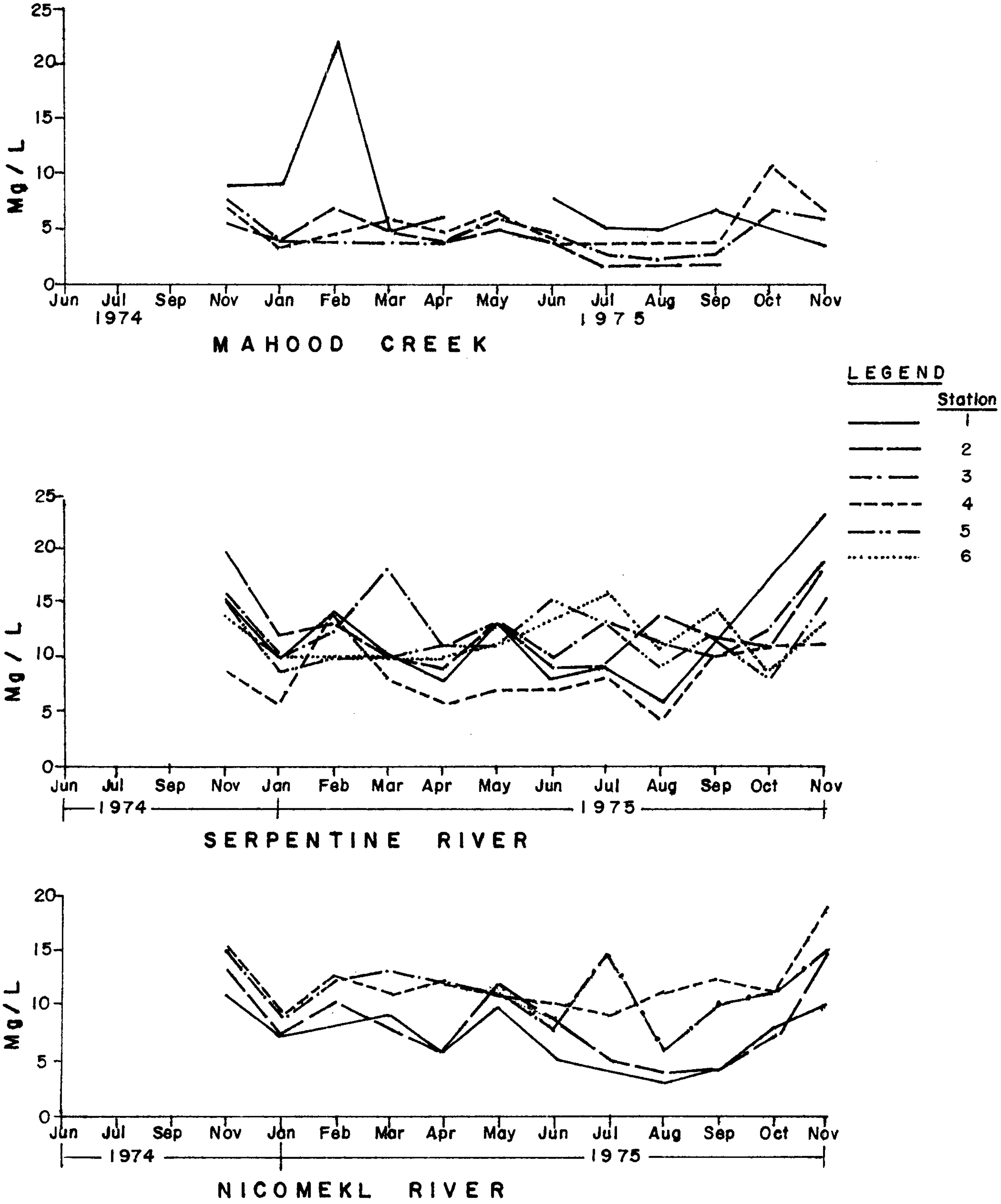


FIGURE 15. TOTAL ORGANIC CARBON LEVELS OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

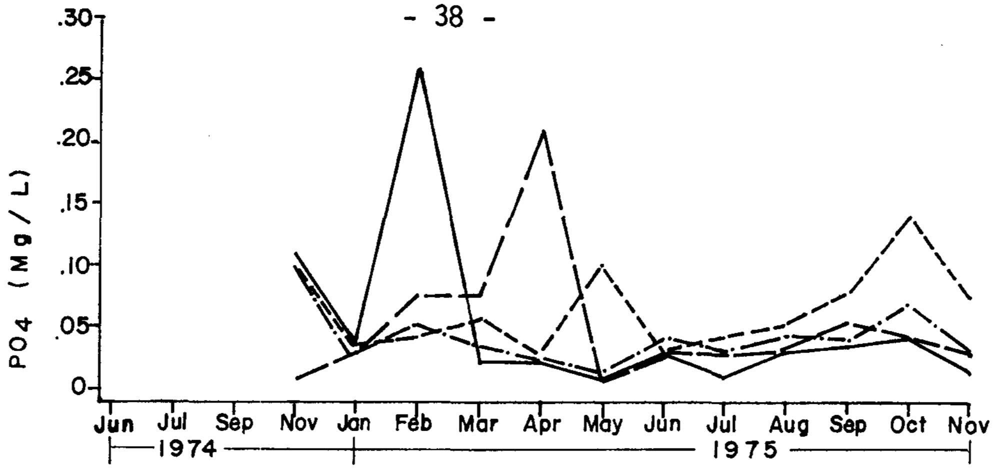
Nicomekl declined markedly at the two upstream stations but remained high at stations 3 and 4. Similarly, carbon levels at stations 1 and 2 on the Serpentine declined in June, however levels increased again in August at station 2 and in September at station 1. The lowlands are farmed more intensely and it is likely that fields here are irrigated more than at the upstream stations. Thus organically rich runoff from irrigated fields probably contributed to higher levels of organic material at the downstream stations during the summer months. Unfortunately, samples were not analyzed for carbon levels in the summer of 1974 so we do not know if the pattern observed in 1975 is characteristic.

In Mahood Creek, carbon levels were high in the winter, peaked with the fall and spring rains, and were lowest in the summer months. The decrease in carbon levels in summer was greatest at stations 2 and 3 where streambanks have the most vegetative cover.

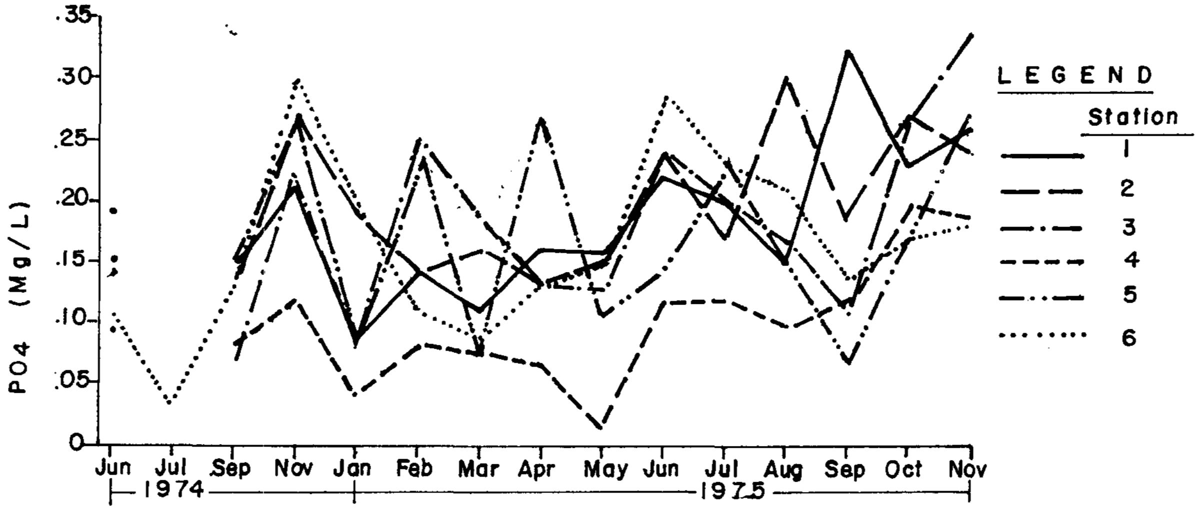
3.1.8 Total Phosphate. Phosphate levels are a measure of water nutrient levels and indicate the potential for organic growth in the stream.

For nine of the fifteen months sampled, phosphate levels at the two downstream stations on the Nicomekl were higher than at upstream stations (Figure 16). However, this difference was not always consistent with season or flow rate so its significance is questionable. In the Serpentine there were no obvious interstation differences other than station 4 where phosphate levels were always reduced by dilution with Mahood Creek water. Seventy percent of samples from Mahood Creek had less than 0.05 mg/l PO_4, whereas in the Serpentine and Nicomekl, respectively, 50% and 63% of samples ranged from 0.05 to 0.15 mg/l PO_4 and the remainder were higher and concentrations up to 1.95 mg/l were recorded.

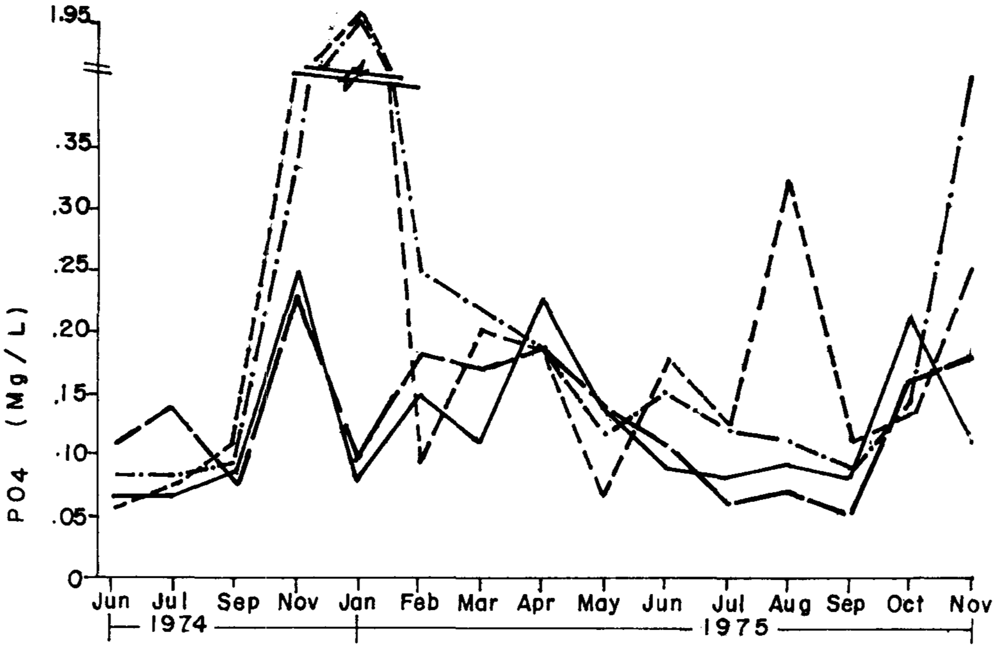
At stations 1 to 3 on the Nicomekl and at all stations on Mahood Creek, phosphate levels declined from June to September then increased again with the fall rains in October or November both years. This trend was not obvious in the Serpentine or at station 4 on the Nicomekl



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

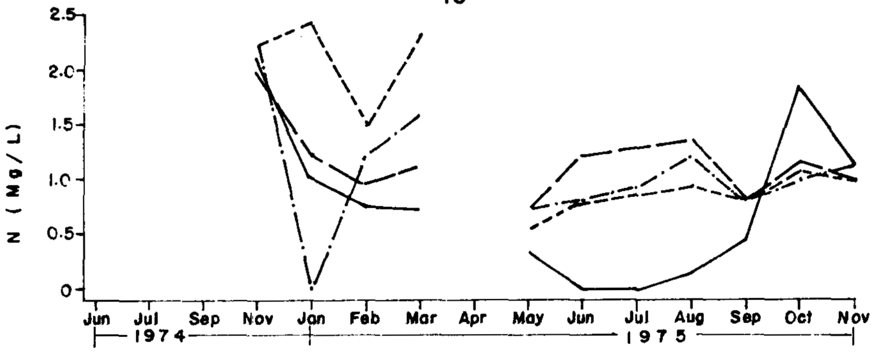
FIGURE 16. PHOSPHATE LEVELS AT STATIONS ON THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

where irrigation runoff from fertilized fields likely kept levels high during the summer.

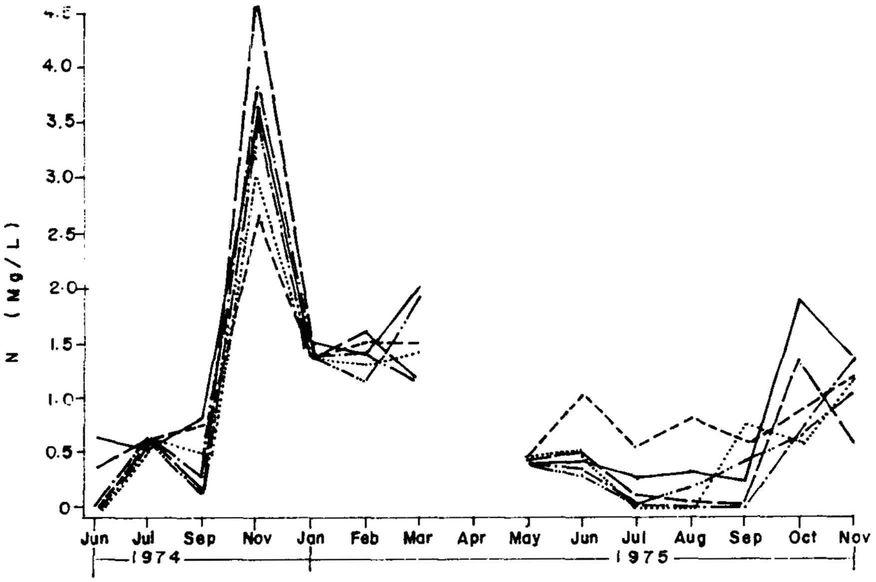
3.1.9 Nitrite-Nitrate Nitrogen. The chief sources of nitrites and nitrates in water are from bacterial conversion of ammonia in domestic sewage, animal wastes, and fertilizer runoff from fields, nurseries, etc., and from decomposing organic matter. The bacterial oxidation of ammonia and nitrites depresses water oxygen levels and the nitrate created is a nutrient which if present in excess can lead to eutrophication of streams.

In 1974 and 1975 nitrite-nitrate levels peaked in the fall at all stations, however 1974 peak levels were two to four times higher (Figure 17). At all stations where bank cover was minimal and agricultural or septic tank runoff greatest, that is at all stations on the Serpentine, except station 4, at stations 3 and 4 on the Nicomekl, and at station 1 on Mahood Creek, nitrite-nitrate levels were low in the spring and summer ($\leq$ 0.5 mgN/l) and high in fall and winter ($\geq$ 1.0 mgN/l). At the other stations, nitrite-nitrate levels were high (0.7 to 1.0 mgN/l) and more stable throughout the year, except during the fall peak. Thus, although there were seasonal variations in nitrite-nitrate levels at stations under greatest agricultural influence, there was no downstream accumulation of nitrite-nitrate nitrogen.

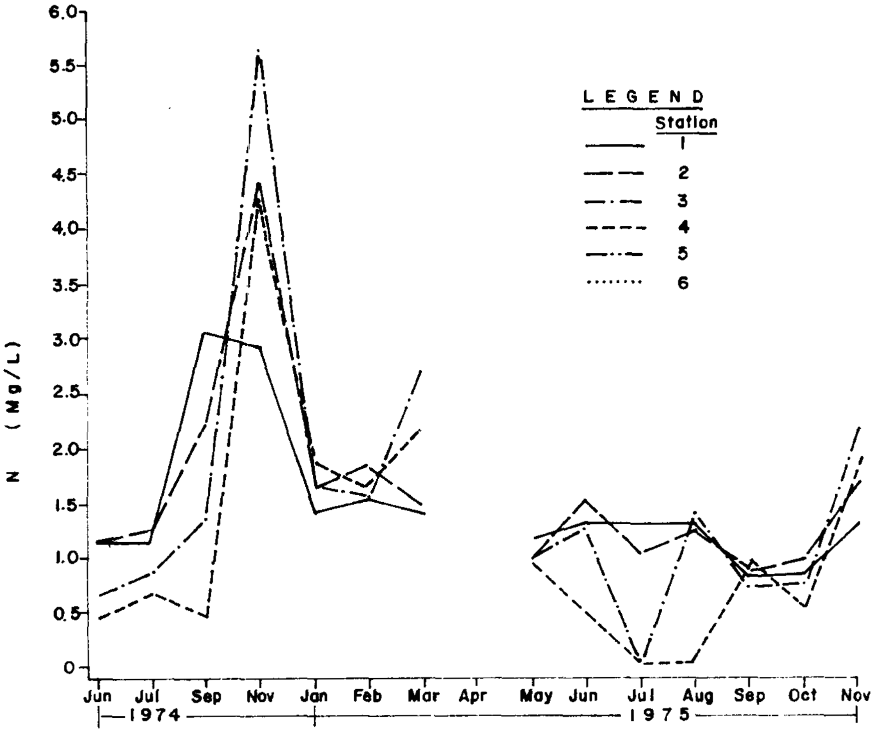
The spring and summer depression in nitrite-nitrate levels at some stations may mean that these nutrients were used by growing algae almost as rapidly as they were formed from ammonia, and/or that nitrates applied to fields were bound up in growing plants and did not run off in irrigation water. Supersaturated oxygen levels during spring and summer at most stations on the Serpentine, at stations 3 and 4 on the Nicomekl, and at station 1 on Mahood Creek tend to confirm that algae growth was high at these stations. The increase in nitrites and nitrates in fall corresponds with a decrease in oxygen saturation and pH which in turn indicates decreased plant growth. It also corresponds with an increase in



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 17. NITRITE-NITRATE NITROGEN CONTENT OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

rainfall and subsequent runoff from agricultural operations as well as an increase in organic matter from dying leaves, grass, etc.

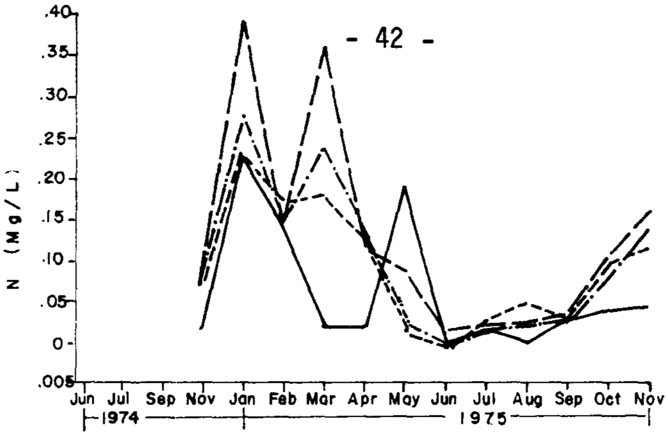
Results were not broken down into nitrite and nitrate concentrations so the toxicity effect on fish of the combined value cannot be interpreted as nitrites are 10,000 times more toxic than nitrates (E.P.A., 1976)

3.1.10 Ammonia Nitrogen(NH_3 + NH_4^+). Ammonia is excreted in human and domestic animal wastes and is a breakdown product of nitrogenous wastes. It is highly soluable in water and in its undissociated form is directly toxic to aquatic organisms (E.P.A., 1976). In addition, the nitrification of ammonia in water consumes oxygen.

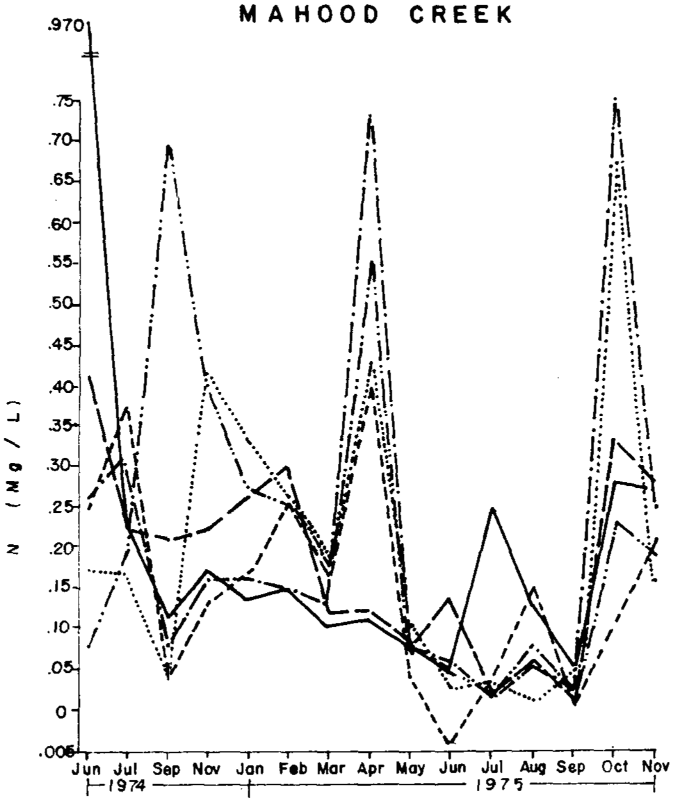
In 1975, ammonia levels at all stations were high and variable during the winter then dropped sharply to less than 0.10 mg N/l in May or June, and remained low until October (Figure 18). This trend was not evident the previous summer, indeed some of the highest ammonia levels were recorded in June, July and September, 1974 at various stations. This difference between 1974 and 1975 levels was also found in nitrite-nitrate levels but the cause of the change in nitrogen input is unknown.

During the summer, ammonia levels were similarly low in all three streams but during the winter, levels were slightly higher in the Nicomekl River. There was no downstream accumulation of ammonia in the Nicomekl or Mahood although in the Serpentine, winter ammonia levels were highest at the last two downstream stations.

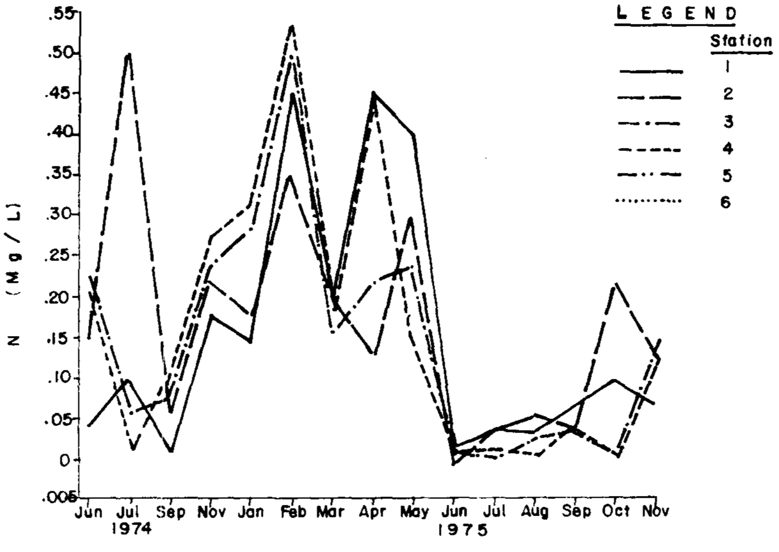
High pH values found in downstream stations on the Nicomekl and Serpentine from June to September (Figure 9), coupled with increased temperatures (Figure 5) would increase the percent of toxic un-ionized ammonia present in water (Thurston, et.al. 1974). Samples were not analyzed for NH_4^+ vs NH_3 content, however in the summer of 1975, total ammonia nitrogen levels were far below levels known to cause lethal or sublethal effects in trout fry (Fromm, 1970; Burrows, 1964), and levels found in the summer of 1974 and winter 1975 would only be harmful if all the ammonia present was un-ionized, which is not likely (Thurston et.al., 1974).



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 18. AMMONIA NITROGEN CONCENTRATION OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

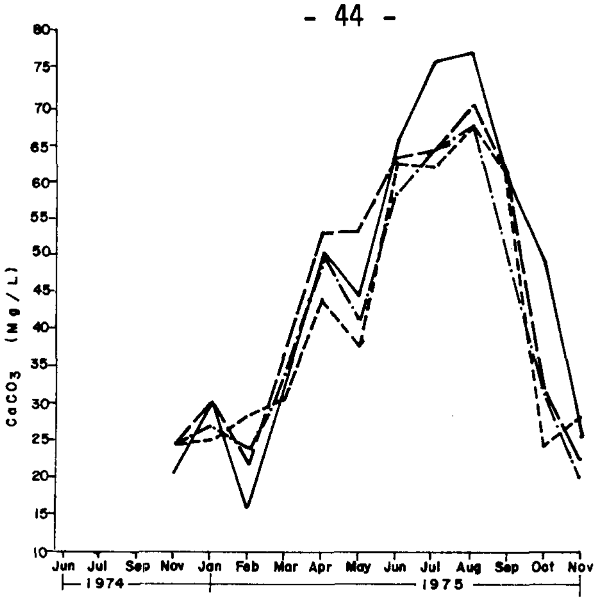
3.1.11 Alkalinity (mg $CaCO_3$/l). Alkalinity is a measure of the buffering capacity of water and thus can affect organisms directly through pH changes or indirectly by altering the toxicity of other chemicals such as ammonia and heavy metals.

Seasonally the alkalinity at all stations sampled was low from November until March (15-30 mg $CaCO_3$/l), and high from spring to fall both years ($\geq$ 40 mg CaCO3/l) (Figure 19). There was no appreciable difference in alkalinity levels between stations or streams. Peak alkalinity levels occurred at the same time as assummed peak photosynthetic activity, even so, pH levels increased at this time.

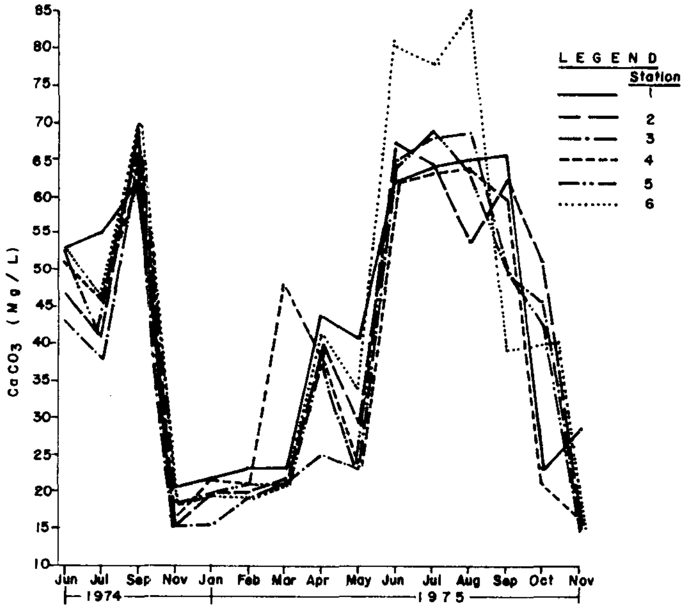
3.1.12 Total Hardness (mg $CaCO_3$/l equivelent). The total concentration of calcium and magnesium salts peaked twice at stations on the Nicomekl and Serpentine Rivers, a lesser peak in April and a major peak in the fall (Figure 20). The fall peak occurred in September and October at the two downstream stations on each river, but usually only in September at stations upstream of these. In 1974, hardness levels at the two downstream stations on the Nicomekl and Serpentine were exceptionaly high until floodgates were installed in the fall and tidal influence at these stations thus minimized. However even with the tidegates in operation, these downstream stations had higher hardness levels than upstream stations. Otherwise, hardness levels were similar between stations and streams.

In Mahood Creek, hardness levels at the two downstream stations were low in the winter of 1974, increased in April, then remained stable until October 1975 when levels dropped again (Figure 20). The pattern was similar at the two upstream stations except that hardness levels also increased sharply in July and September at station 1 and in September at station 2. Other than these peaks, hardness levels were similar from station to station.

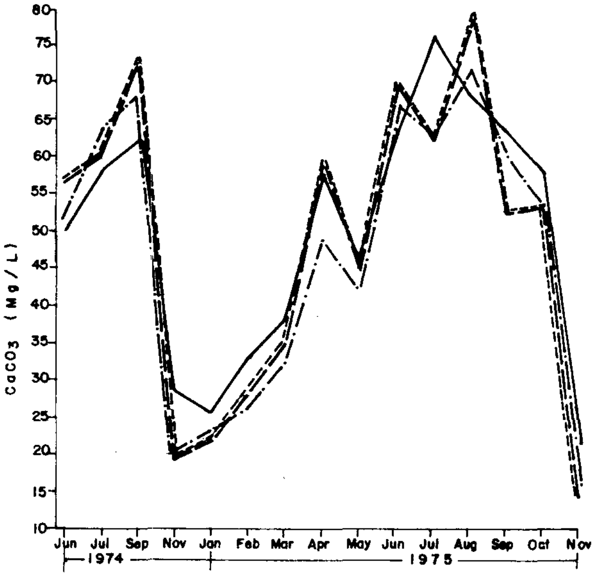
3.1.13 Conductivity. Conductivity is a measure of the total concentration of ions. A seasonal pattern of change in ion concentration was



MAHOOD CREEK

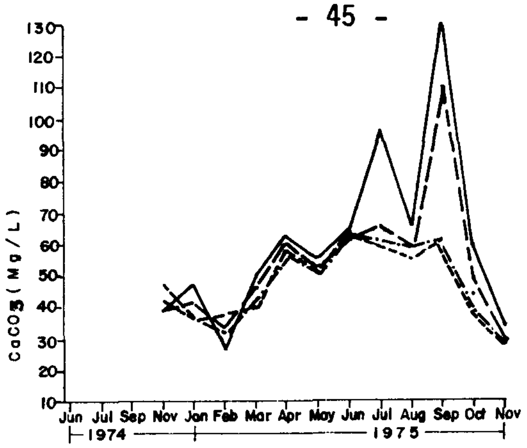


SERPENTINE RIVER

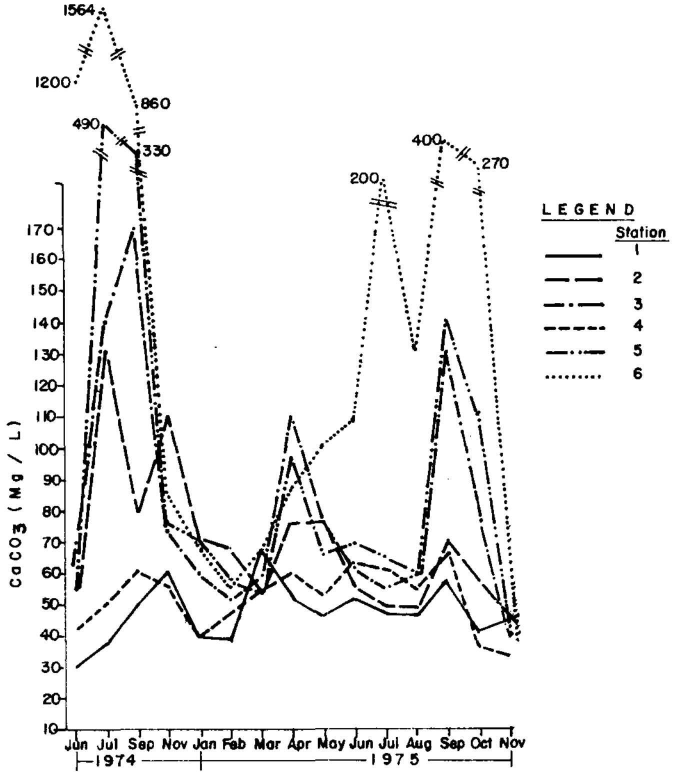


NICOMEKL RIVER

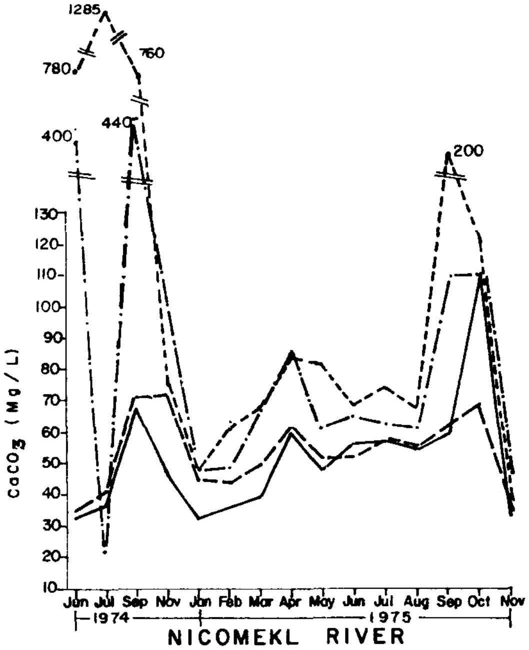
FIGURE 19. ALKALINITY OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975



MAHOOD CREEK



SERPENTINE RIVER



NICOMEKL RIVER

FIGURE 20. TOTAL HARDNESS OF WATER SAMPLED FROM THE NICOMEKL AND SERPENTINE RIVERS AND MAHOOD CREEK IN 1974 AND 1975

evident in the Serpentine and Nicomekl where conductivity was high in the summer of 1974, declined to the lowest level in January 1975, then increased again through spring and summer before decreasing sharply in November (Figure 21). This pattern is essentially the same as for measure ments of alkalinity. However, while conductivity was much higher at the two downstream stations of both streams during the summer prior to the installation of floodgates than during the following summer, alkalinity concentrations were similar both years.

In Mahood Creek, conductivity was also lower in winter and higher in summer except at stations 1 and 2 where levels in January and February were as high as summer values. This increase in conductivity in winter was not found in alkalinity measurements. Conductivity levels were generally lower in Mahood Creek than in the Nicomekl and Serpentine and the difference between winter and summer values was not so extreme.

3.2 Macroinvertebrate Populations

The density and species composition of macroinvertebrate populations is used routinely to indicate water quality. However, macroinvertebrates are also affected by stream bottom composition, water temperature, flow, and fluctuating water levels (Hynes, 1970; Cairns et.al., 1971; Whitton, 1975).

Organisms classed as pollution "sensitive" (Servizi and Burkhalter, 1970) were found only at stations 1 and 2 on Mahood Creek and in few numbers at station 1 on the Nicomekl (Figure 22). However one would not expect these organisms at the other stations since all but station 3 on Mahood Creek have deep mud bottoms and organisms classed as pollution sensitive do not normally live on mud bottoms, regardless of other water quality factors. Gravel at station 3 was fairly heavily sedimented so again, pollution sensitive organisms should not be expected and were not found.

The number of "moderately tolerant" and "tolerant" organisms found was greatest at the two upstream stations on the Nicomekl but numbers decreased markedly at the two downstream stations. Far fewer organisms generally, were found at stations in the Serpentine, particularly stations 3 and 5. Almost no oligochaetes were found at stations 5 and 6 on the Serpentine or at station 4 on the Nicomekl where one would have expected large numbers of these tolerant animals. However, during the survey period the lowland portion of the Nicomekl and Serpentine Rivers were dredged extensively to re-establish the dikes. Water levels here fluctuated sharply over the winter and the overall water level increased approximately two meters.

Samples taken on Mahood Creek are not camparable to those taken on the mainstem rivers because of the different sampling technique used. Tolerant and moderately tolerant varieties were found at all stations although the number of organisms was unexplainably low at station 3.

3.3 Periphyton Populations, Pigment Content and Ash Weight.

3.3.1 Periphyton Populations. Since the arrangement and assembly of algae in streams are highly dependent on the type of substrata (Whitton, 1975), and river flow (Hynes, 1970), the positioning and type of artificial substrate used to sample algae populations may itself be a selective factor in the type of algae sampled. Also, artificial substrates only show attached algae forms and by no means give the total algae biomass present in a stream.

In late June and early July, 1975, colonial diatoms were the most abundant algae found on the glass slides at stations 2, 3, 4, 5, and 6 on the Serpentine and at station 2 on the Nicomekl (Table 3). Meridion circulare was the dominant species found at all stations in the Serpentine ranging from 12,000 to 150,000 cells per cm^2. However, at station 2 on the Nicomekl only 430 cells per cm^2 were found of this species; instead, Tabellaria cells were more common (10,000 cells per cm^2). Other abundant algae were the diatoms: Surirella, Cyclotella, Eunotia, Cocconeis, Navicula and unknown Bacillariophyceae; as well as the green

TABLE 4 SIZE AND COMPOSITION OF ALGAE POPULATIONS COLLECTED FROM THE NICOMEKL AND SERPENTINE RIVERS IN JUNE AND JULY 1975.

ALGAE	River:	NICOMEKL	SERPENTINE					
	Sample Site:	2	2	3	4	4	5	6
	Sample Date:	July 11	June 26	June 26	June 6	June 26	June 26	June 26
	No. days slide submerged:	14	19	19	13	19	19	19
	Sample Volume: (ml)	365	365	370	315	377	325	370
		(Number of cells per cm^2 of slide surface)						
Chlorophyta								
Cladophora (Pithophora?)		-	-	-	-	-	6700	47000
Closterium		-	-	-	72	-	-	-
Hydrodictyon		-	-	-	160	-	-	-
Oedogonium		350	4000	12000	960	500	3650	P
Ulothrix		3900	-	P	-	-	1700	-
Scenedesmus		-	325	-	1760	-	2300	-
Colonial cells		P	P	P	-	300	P	P
Chrysophyta								
Bacillariophyceae		P	700	870	2700	168000	3660	4800
Achnanthes		-	-	-	450	880	600	-
Amphora		-	700	-	P	-	P	-
Cocconeis		P	P	570	20000	1800	600	330
Cymbella		-	-	-	-	-	600	-
Diploneis		-	350	280	-	-	-	-
Eunotia		1500	800	2500	24000	9700	1200	P
Fragilaria		-	-	P	-	-	P	P
Gomphonema		-	-	-	-	-	-	-
Gyrosigma		-	-	80	-	-	-	-
Meridion circulare		430	12000	12200	105000	150000	27000	28000
Navicula		P	P	800	-	-	12000	75000
Nitzschia		-	-	-	-	-	600	-
Pinnularia		-	680	560	P	-	-	-
Surirella		1070	4800	50	240	480	3700	2500
Synedra		-	350	50	-	-	-	1700
Tabellaria		10000	3350	300	-	600	600	5500
(Centric)		500	700	P	-	220	250	500
Melosira		-	-	-	-	-	300	P
Cyclotella		-	200	-	60000	-	21000	P
Cyanophyta								
Oscillatoria		-	-	-	500	1800	P	P
Unicells, possible Euglenophyta		-	-	-	-	-	9000	-
Total algal cells^1 x 10^3		18	29	30	215	332	95	165

1 = rounded to the nearest 1,000

P = present

algae Oedogonium and Cladophora. Except for Meridion, the presence and abundance of these other algae varied markedly from station to station, and from the beginning of June to the end of June at the one station, 4, where these two samples were analyzed.

Some obvious differences were found in algae populations between upstream and downstream stations on the Serpentine. Pinnularia were found only at stations 2 and 3, and Oedogonium were more abundant upstream and not present at station 6; Cladophera were found only at the downstream stations 5 and 6, and Navicula were far more numerous at stations 5 and 6. It is interesting that although Meridion were twice as abundant at stations 5 and 6 than at 2 and 3 and, in total, algae were more abundant downstream than upstream, by far the largest algae populations were found at the midstream station 4. This station is immediately downstream of Mahood Creek and could be classed as the cleanest in the Serpentine.

There was no trend in the number of different kinds of algae found at stations in the Serpentine, 9 were found at station 6, 18 at station 5 and 11-13 at the upstream stations. The sample analyzed from the Nicomekl was in the water for 5 fewer days than the Serpentine samples which is why fewer cells were counted in this sample. However, regardless of this time difference, only seven different types of algae were found at this station, substantially less than at upstream stations on the Serpentine.

3.3.2 Pigment Content of Algae Samples.

Chlorophyll-a levels in samples from the Serpentine peaked three times from March to September, 1975: first during May at all stations; second in the last two weeks in June and first two weeks in July, but only at stations 5 and 6; and again, during September at stations 3, 5 and 6 which were the only station not vandalized (Table 5). At station 2 in the Nicomekl, Chlorophyll-a levels increased in May, peaked in early June at 0.58 ug cm^2/day, then slowly decreased to a low of 0.02 ug cm^2/day by mid August. Phaeopigment content was usually low, $>$ 0.02 ug/cm^2/day, except in April and early

TABLE 5 CHLOROPHYLL-A AND PHAEOPIGMENT CONTENT, AND BIOMASS OF PERIPHYTON SAMPLES COLLECTED MONTHLY FROM THE SERPENTINE AND NICOMEKL RIVERS IN 1975.

	River:	NICOMEKL			SERPENTINE				
	Station:	2	3	4	2	3	4	5	6
Date sampled (No. days immersed)	Parameter ug/cm^2/day X 10^{-2}				ug/cm^2/day X 10^{-2}				
March 14	Chlorophyll-a	3.2	8.6	3.0	10.0	4.3	-	3.2	8.6
(28)	Phaeopigments	0.7	1.4	8.2	2.1	0.7	-	0.7	1.8
	Biomass	16.1	-	17.1	18.2	4.3	33.2	11.1	9.6
April 22	Chlorophyll-a	5.0	4.7	5.8	3.7		11.8	2.1	2.4
(38)	Phaeopigments	1.0	1.0	3.9	8.9	-	13.9	1.8	1.0
	Biomass	14.7	-	-	2.1	1.6	2.4	1.8	0.8
May 23	Chlorophyll-a	40.7	-	1 0.7	29.7	14.0	26.0	41.7	21.3
(30)	Phaeopigments	0.03	-	2.0	4.0	-	2.0	0.03	0.03
	Biomass	17.3	-	-	1.0	6.0	11.0	7.7	9.0
June 6	Chlorophyll-a	58.5			7.7	6.2	9.2	9.2	3.1
(13)	Phaeopigments	13.8			2.3	3.1	1.5	6.9	0.8
	Biomass	2.3			3.1	7.7	3.8	7.7	28.5
June 26	Chlorphyll-a	40.5			6.3	16.8	14.2	39.5	57.9
(19)	Phaeopigments	0.05			0.05	0.05	0.05	0.05	0.05
	Biomass	0.0			3.1	7.9	4.2	3.3	5.3
July 11	Chlorphyll-a	32.1			5.7	10.7	12.1	19.3	107.8
(14)	Phaeopigments	1.4			7.8	-	5.0	7.1	0.07
	Biomass	1.4			5.7	5.0	-	15.0	29.2
July 25	Chlorophyll-a	6.9			2.3	3.1	4.6	4.6	5.4
(13)	Phaeopigments	0.7			1.5	3.8	1.5	3.8	4.6
	Biomass	-			-	52.3	-	27.7	712.3
Aug. 19	Chlorphyll-a	1.7			1.7	2.9	-	7.1	5.8
(24)	Phaeopigments	0.8			0.8	2.1	0.04	3.8	1.7
	Biomass	-			-	-	-	21.2	53.3
Sept. 18	Chlorphyll-a	-				29.3		39.6	41.7
(29)	Phaeopigments	-				4.1		21.0	20.3
	Biomass	-				-			

June when samples from some stations on the Serpentine increased to as high as 0.14 ug/cm^2/day. There was no pattern in phaeopigment content between stations or sample periods and no co-relation with chlorophyll-a content.

Unfortunately, the number of days that the artificial substrates were submerged differed between sample periods, so for comparison purposes the data has been expressed as ug/cm^2/day emersed. However, as colonization of the substrate is not likely linear with time, this method of expressing the data is not exact and this must be kept in mind when comparing data between sample periods.

3.3.3 Dry and Ash Weight of Algae Samples. Theoretically the dry weight of material scraped off the artificial substrates represents the weight of living matter, detritus and sediment, whereas after burning the ash weight represents only inorganic matter. Thus the difference between these weights can be construed as biomass. This data is presented in Table 4 and has been calculated as ug/cm^2/day x 10^{-2} of biomass. Biomass values for the Serpentine River ranged from 4.3 to 18.2 units in March, decreased to less than 3 units in April, then stabilized at around 1 to 10 units until July when values increased markedly at stations 3, 5 and 6. Unfortunately results are not available after mid July for the other stations. At station 2 on the Nicomekl, biomass values remained between 15 and 20 units until the end of May before decreasing sharply to between 1 and 2 units, again results are missing after mid July. High values in spring may be due to detritus rather than growing algae.

Statistical correlations between biomass, chlorophyll-a content and oxygen saturation (Figure 7) have not been done, however there is no visible relationship between these parameters. Oxygen saturation did increase at downstream stations during the summer as did biomass values, however samples were not taken at the same time or frequently enough for us to say these values are correlated. Biomass values in no way correspond with chlorophyll-a content on the substrates and this difference may be due to an error or poor accuracy in one or both techniques, or due to the small sample number. The E.P.S. Laboratory Manual claims an accuracy for chlorophyll-a at the 5 ug level and, as most of our results were less than 5 ug, the values given for chlorophyll-a are thus suspect.

3.4 Metal Levels in Fish Muscle Tissue

Metal levels are shown in Table 6. There were no interstation differences found in metal levels of sculpins, the only fish caught consistently at almost all stations. There were also no consistent differences in sculpin metal levels between the three rivers sampled. Stickleback, trapped only at station 1 in Mahood Creek, was the smallest fish caught and had consistently higher levels of all metals measured than the trout trapped at the same station. Trout, which like Stickleback feed in mid water or at the surface, had metal levels similar to that of the bottom feeding prickly sculpin and brown bullhead.

Calcium levels were the only measurement that varied widely from sample to sample and this was likely due to contamination of the sample with bone fragments.

TABLE 6 MUSCLE METAL LEVELS IN FISH SAMPLED FROM STATIONS ON THE SERPENTINE AND NICOMEKL RIVERS AND MAHOOD CREEK IN JULY AND AUGUST 1974.

	Sample Station	Family[1] Code	Species of Fish	Number[2]	$\bar{x}$ Fork Length cm	$\bar{x}$ Body Weight gm	METALS[3] (ug/gm of muscle)											
							Ca		Mg		Cu		Zn		Fe		Mn	
							Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
SERPENTINE	1	D	Sculpin	6	9.4	11.5	12000	2800	1400	320	3.0	0.7	210	49	36	8.5	10.0	2.5
		E	Bullhead	2	12.3	23.8	1200	260	1200	250	1.5	0.3	60	13	9	2.0	1.5	0.3
	2	E	Bullhead	4	14.6	41.9	1500	305	1300	260	2.8	0.46	55	11	65	13.0	3.2	0.6
		D	Sculpin	4	12.9	32.7	2300	490	1250	270	1.9	0.4	75	16	18	3.8	2.8	0.6
	3	C	Peamouth	1	15.8	38.4	5600	1300	1300	320	2.7	0.6	95	23	47	10.0	4.4	1.0
		D	Sculpin	3	12.4	25.8	4800	1000	1200	260	2.1	0.5	65	14	120	25.0	3.7	0.8
	4	E	Bullhead	1	15.5	48.7	9600	2200	1420	340	1.8	0.4	85	20	29	3.4	3.4	0.8
		D	Sculpin	7	12.2	23.8	5900	1200	1200	240	1.5	0.3	65	14	21	4.7	3.6	0.7
	5	E	Bullhead	1	16.9	60.4	4900	1200	1300	310	2.3	0.6	100	28	18	4.5	6.0	1.4
		D	Sculpin	6	12.9	34.4	4900	1000	1000	220	1.9	0.4	65	14	21	4.4	2.8	0.6
	6	C	Peamouth	3	14.3	38.6	9300	1600	1300	230	2.8	0.5	55	10	33	6.0	3.0	0.6
		E	Bullhead	5	13.8	29.0	3900	620	1100	180	2.9	0.3	49	8	27	4.3	1.8	0.3
MAHOOD CREEK	1	A	Trout	2	7.9	4.7	13000	2900	1500	330	2.7	0.6	90	21	25	5.5	6.5	1.5
		B	Stickleback	8	4.5	0.97	57000	1400	1800	450	7.0	1.7	110	27	85	20.0	47.0	11.0
	2	A	Trout	1	14.3	3.9	12000	3000	1300	320	2.6	0.6	70	17	25	6.0	5.5	1.3
	3	A	Trout	1	13.9	27.2	10000	1600	1300	320	1.8	0.4	55	14	25	6.0	9.0	2.2
		D	Sculpin	1	13.4	31.2	28000	5100	1500	290	2.4	0.5	130	26	33	7.0	10.0	2.1
	4	D	Sculpin	2	11.6	20.2	10000	2200	1300	230	1.8	0.4	80	18	38	8.0	2.7	0.6
NICOMEKL	1	D	Sculpin	5	11.8	23.6	4200	900	1000	220	2.0	0.4	44	9	20	4.3	3.0	0.6
		D	Sculpin	5	11.9	25.0	3100	650	900	190	1.5	0.3	50	11	16	3.4	2.4	0.5
	2	D	Sculpin	5	11.3	20.0	5000	1000	940	190	1.6	0.3	48	10	25	5.0	3.0	0.6
		D	Sculpin	5	11.7	21.3	4000	870	820	170	1.5	0.3	55	12	21	4.5	2.9	0.4
	3	D	Sculpin	5	14.3	41.9	5200	990	1000	290	1.9	0.3	65	12	17	3.1	2.1	0.4
		D	Sculpin	5	13.2	32.8	7200	1400	1300	260	2.5	0.5	65	12	47	4.5	2.9	0.6
	4	D	Sculpin	5	12.8	30.5	5500	1100	1100	230	1.7	0.3	60	12	21	4.4	2.5	0.5
		D	Sculpin	5	13.7	40.5	13000	2900	1500	330	4.0	0.8	70	15	65	14.0	3.6	0.8

[1] CODE FOR FAMILY
A - Salmonidae
B - Gasterosteidae
C - Cyprinidae
D - Cottidae
E - Ictaluridae

[2] A section of muscle was removed from each fish and sections from the same species pooled and analyzed as one sample.

[3] Method is accurate to ± 10% for Zn, Fe and Mg but only to ± 30% for Mn and Cu because these values are close to the detection limits for these metals.

NOTE: Both the wet (acid) method and the low temperature, dry ash, method were used for metal analyses as described in the Environment Canada - Fisheries Service Laboratory Manual (1974).

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APPENDICES

APPENDIX I

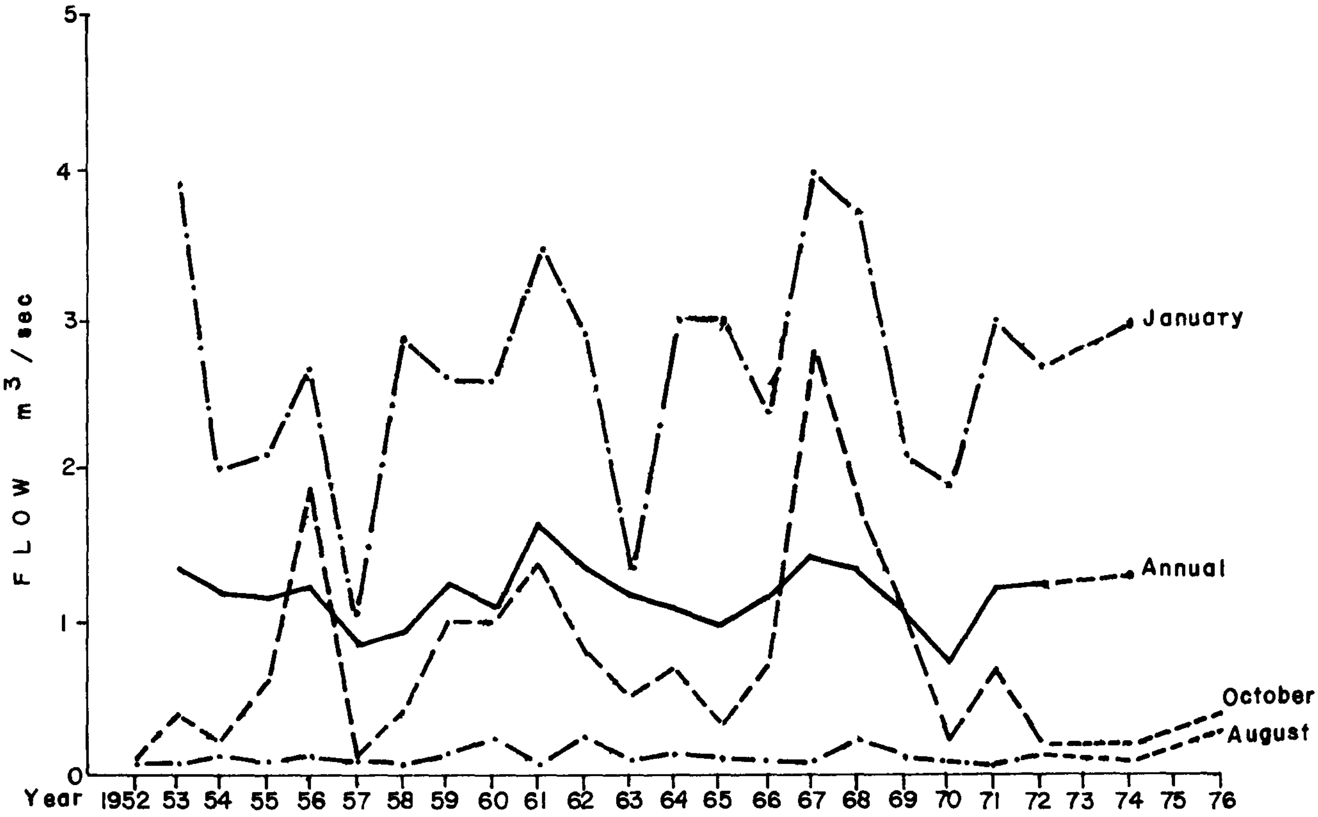
STREAM FLOWS, SOIL TYPES AND LAND USE IN THE NICOMEKL-SERPENTINE WATERSHED

APPENDIX I (TABLE 1I) ESTIMATED MAXIMUM AND MINIMUM DAILY FLOWS (m^3/sec) IN THE NICOMEKL RIVER AND MAHOOD CREEK, COMPILED FROM WATER SURVEY OF CANADA DATA[1]

	Nicomekl River	Mahood Creek
January high flows:		
Highest recorded daily flow	28.3*	28.3*
Estimated 2-year recurring	20.4	11.2
" 10- " "	25.5	22.7
" 20- " "	27.8	27.6
" 100- " "	33.0	39.1
Mean monthly maximum flow	18.8	12.2
August low flows:		
Lowest recorded daily flow	0.09	0.0
Estimated 2-year recurring	0.12	0.0
" 10- " "	0.08	0.0
" 20- " "	0.06	0.0
Mean monthly minimum flow	0.10	0.07

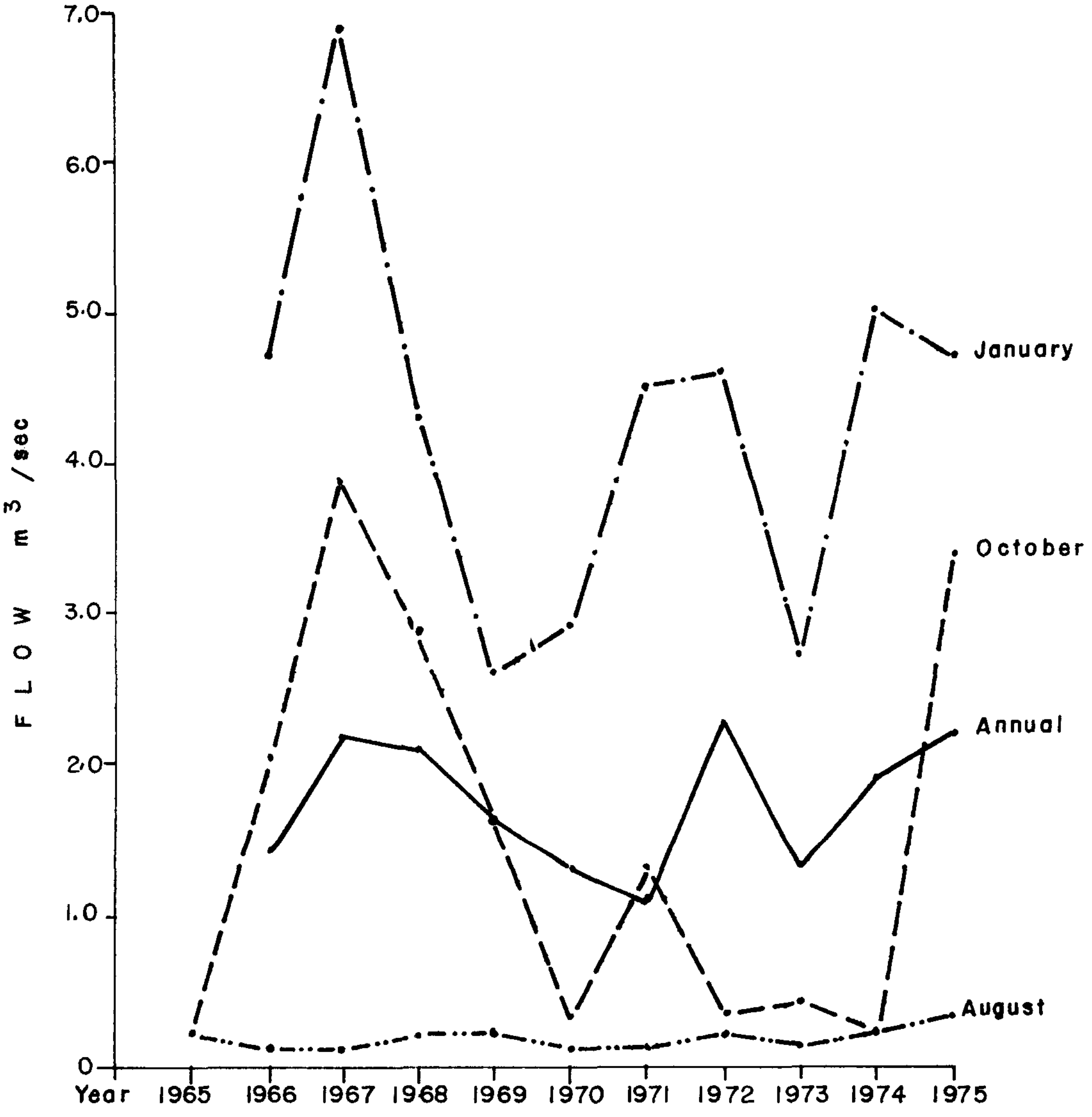
*Estimated flows (=1000 cfs)

[1] From Hirst et al. (1979).



APPENDIX I

FIGURE II MEAN ANNUAL AND MONTHLY FLOWS FOR MAHOOD CREEK RECORDED BY WATER SURVEY OF CANADA AT STATION 8MH - 020 (Hirst et al, 1979)



APPENDIX I

FIGURE 2I MEAN ANNUAL AND MONTHLY FLOWS FOR THE NICOMEKL RIVER RECORDED BY WATER SURVEY OF CANADA AT STATION 8MH-105 (Hirst et al. 1979)

APPENDIX I (TABLE 2I) PRINCIPAL SOIL GROUPS IN THE SERPENTINE-NICOMEKL LOWLANDS AND THE ADJACENT UPLANDS[1]

Group	Origin	Surface pH	Organic matter Percentage	Conductivity value	Total area (ha)*
Organics (humisols and mesisols)	Organic veneers and blankets overlying gleyed marine sediments	4.4-4.8	100	0.4 - 1.1	3406
Saline organics	Thin riverine sediments mixed into underlying decomposed peat	4.5	48	2.1	60
Gleysols (orthic, humic and rego gleysols)	Silty fluvial deposits overlying marine deposits	4.8-5.9	6-30	0.3 - 0.6	1071
Saline gleysols	Recent marine sediments overlying decomposed peat	4.8	16	2.4	587
Upland podzols and gleysols	Washed and unwashed marine deposits, incl. raised beaches	3.6 and higher	5-53	**	1241

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* Total area as measured within lowlands inside 15 m contour

[1] From Hirst et al. (1979). Based on Sprout and Kelley (1961).

APPENDIX II

METHODS FOR WATER QUALITY ANALYSES

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METHODS FOR WATER QUALITY ANALYSES[1]

Parameter	Sample Size (ml)	Preservation	Method of Analysis
Dissolved oxygen	300	fixed in field 2ml $MnSO_4$ + 2ml alkaline iodide-sodium azide	Iodometric-azide modification of the Winkler titration method
Turbidity	50	store 4°C for 24 hr.	Nephelometer photocell
Colour	100	store 4°C for 24 hr.	Platinum-cobalt-visual comparison: Hellige Aqua Tester
Conductivity	200	store 4°C for 24 hr.	Radiometer Conductivity meter and cell
Total Hardness	200	store 4°C for 24 hr.	EDTA titration method
Alkalinity	250	store 4°C for 24 hr.	Potentiometric titration with sulfuric acid
Residue:			
Total	200	store 4°C for 24 hr.	Evaporate 12 hr. at 90°C; dry 1 hr. at 103°C; weigh
Total Volatile	200	store 4°C for 24 hr.	Residue ignited at 550°C; weigh remains
Non-filterable	200	store 4°C for 24 hr.	Filter; dry as for residue; weigh
Total Phosphates		store 4°C for 24 hr	Molybdate-ascorbic acid reduction; colorimetric
Total Organic Carbon	300	store 4°C for 24 hr. keep dark	Combustion, infra-red carbon analyzer
NO_3 - NO_2	100	4mg $HgCl_2$; store at 4°C	Technicon automated colorimetric method
Ammonia	200		Orion selective ion electrode

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[1] Environmental Canada Laboratory Manual, February 1974, Fisheries Service - Environmental Protection Service, Environment Canada, Government of Canada.

APPENDIX III

CLASSIFICATION OF MACROINVERTEBRATES AS TO POLLUTION SENSITIVITY

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CLASSIFICATION OF MACROINVERTEBRATES AS TO POLLUTION SENSITIVITY

Pollution Tolerant

Oligochaeta
  Plesiopora Tubificidae
            Naididae

Polychaeta Nereidae

Moderately Tolerant

Diptera
  Tendipedidae
  Tipulidae
  Empididae
  Rahgionidae
  Tabanidae
  Simulidae
  Ceratopogonidae

Hydracarina
  Hydrachnidae
  Ocari

Coleoptera
  Halipidae
  Hydrophilidae
  Dystiscidae

Isopoda
  Ascillidae

Amphipoda
  Gamarida
  Corophiidae

Pulmonata
  Physidae
  Planorbidae

Hydroida
  Hydridae

Pelecypoda
  Sphaeriidae

Tricladida
  Planariidae

Sensitive

Ephemeroptera
  Bactidae
  Heptageniidae

Plecoptera
  Perlodidae
  Nemouridae
  Chloroperlidae

Trichoptera
  Limnephilidae
  Lepidostamitidae

Homoptera
  Aphididae

Megaloptera
  Sialidae

Others

Phynchobdellidae
  Glossifphoniidae

Fish (Minnow)